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Volume 25 DECEMBER 28, 1950 Number 6

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

LOS ANGELES MEETING

AT

UNIVERSITY OF CALIFORNIA

DECEMBER 28, 29, AND 30, 1950

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SIX ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published six times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published six times a year, once in February, once in March, once in April, once in June, once in November, and once in December, at Prince and Lemon Streets, Lancaster, Pennsylvania.

Address correspondence to Prince and Lemon Streets, Lancaster, Pa., or to Secretary Karl K. Darrow, Columbia University, New York 27, New York.

Entered as second class matter, December 27, 1949, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized Nov. 30, 1948.

DECEMBER 28, 1950 Vol. 25, No. 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

LOS ANGELES MEETING, DECEMBER 28, 29, and 30, 1950

THE 302nd meeting of the **American Physical Society** will be held at the University of California, Los Angeles, on **Thursday, Friday, and Saturday, December 28, 29, and 30, 1950.** There will be a concurrent symposium of our Division of Fluid Dynamics. Its morning session on Friday, December 29, will be devoted to the subject of "Turbulence, Theory and Experiment," and the afternoon session on the same day will discuss "Hydrodynamics of Rarefied Gases." Both of these sessions will be held in Room 147, Business Administration and Economics. Invited papers will be given by J. M. Burgers, C. C. Lin, H. Liepmann, H. Grad, E. D. Kane, and J. R. Stalder. Invited papers on the regular programme of the Society will be given by E. W. Cowan, Robert Serber, Leon Linford, B. E. Cohn, E. J. Workman, W. B. Pietenpol, John Wheeler, G. L. Weissler, and Victor H. Regener.

A **registration desk** will be located in Room 100, Physics-Biology building. Information and maps will be available there, and messages may be left for persons attending the meeting. There will be plenty of convenient parking spaces on the campus and these will be clearly indicated on the maps.

Information regarding **hotels, motor courts, and eating places** will also be available at the registration desk. Inquiries addressed to the Department of Physics regarding living accommodations will be gladly answered.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on 30 January 1948, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of papers of which the abstracts are received not later than Friday, December 22." These abstracts must reach the office of Dr. J. Kaplan (University of California, Los Angeles 24, California) by the specified time. Do not regard this as a guarantee of acceptance. The idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are accepted will not be published: the titles will be announced, and the papers will be scheduled for presentation at a convenient time or times during the meeting.

Prospective meetings of the Society are scheduled to be held at Columbia University, New York City, on February 1–3, 1951; at Pittsburgh on March 8–10; and at Washington on April 26–28.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session will be announced by the Secretary at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in fewer than ten minutes, or may read it by title.

The abstracts of the papers contributed to the Los Angeles meeting, which follow hereinafter, will be reprinted in *The Physical Review* exactly as they stand here. The procedure for submission of errata is described in the Washington Bulletin and in the Oak Ridge Bulletin; the errata must be received by Miss Ruth Bryans, 57 East 55th Street, New York 22, New York, not later than January twelfth. The type cannot be altered to even the slightest extent without forfeiting the economies for the sake of which the new policy has been adopted. *Under no circumstances send* your original abstract to Miss Bryans with alterations marked upon it; write out the errata (examples, far too numerous, can be found in *The Physical Review*).

Speakers must retrieve their lantern slides before leaving the hall in which their papers were given. The Local Committee is under no obligation to keep or to return them.

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

DEC 26 1950

PROGRAMME

THURSDAY MORNING AT 10:00

Room 19, Chemistry Building

(CARL D. ANDERSON presiding)

Contributed Papers

A1. Stopped Mesons in Pb and C Observed in a Cloud Chamber at Sea Level Triggered by Neutron Coincidences.* EDWARD J. ALTHAUS,† *Washington University.*—A large square cloud chamber containing six plates of Pb (5.9 g/cm²) and five of C (3.1 g/cm²) arranged alternately was triggered by an overhead fourfold crossed G-M tube telescope in long-gated coincidence with B^{10} neutron detectors. These were embedded in a C-shaped block of paraffin surrounding the chamber. Stopped μ-mesons were identified by ion density at least 2½ times the minimum in the first compartment above the plate and absence of an accompanying event in order to eliminate locally produced π-mesons. In 1215 neutron coincidence sets of pictures, 16 definite cases were observed in Pb and one in C. No decay electrons were evident. Of 1286 sets with G-M control alone, roughly equal numbers were observed in each material with some decay electrons. These findings agree with the results of other experiments[1] showing neutron emission from stopped mesons in Pb, and are consistent with the low capture probability for μ^- in C, but the results do not show whether or not capture in C leads to neutron emission.

* Research assisted by the joint program of the ONR and AEC.
† Now at University of Southern California.
[1] Sard, Conforto, and Crouch, Phys. Rev. **76**, 1134 (1949). Fowler, Sard, Fowler, and Street, Phys. Rev. **78**, 323 (1950).

A2. Energy Spectrum at 18° of Mesons Produced in Proton-Proton Collisions. VINCENT PETERSON,* EDWIN ILOFF, AND DORA SHERMAN, *University of California, Berkeley.*—Using a liquid hydrogen "point" source and photographic plate method of detection described earlier,[1] the energy spectrum of positive mesons produced from 340-Mev proton bombardment has been measured at a laboratory angle of 18°±0.85°. Improvements in the energy and angular resolution of the detector geometry have resulted in narrowing the half-width of the sharp peak at the upper end of the spectrum to ±1.8 Mev, most (if not all) of which is due to the energy spread of the primary proton beam. Present uncertainties in the meson mass and absolute accuracy of the proton range-energy relationship prevent the use of energetics in determining the existence of $p+p \rightarrow d+\pi^+$; however, if independent experiment confirms that the peak corresponds to this reaction, then the mean energy is a sensitive measure of meson mass. The integrated cross sections at 18° and 30° are, respectively, 0.163 and 0.058 mb/ster (+15 percent, −5 percent). The ratio 18°/30°=2.8 favors a $\cos^2\theta$ angular distribution in the center-of-mass system.

* Now at California Institute of Technology.
[1] Post-deadline paper by V. Peterson at 1950 Washington, D. C., meeting; Phys. Rev. **80**, 136 (1950).

A3. An Automatic Ionization Chamber.* H. V. NEHER, *California Institute of Technology.*—For studying fluctuations of cosmic rays at balloon altitudes an automatic ionization chamber has been designed. A small, gold-coated quartz fiber is mounted at one end of, and at right angles to, an insulated collecting rod. When the potential of the collector drops to about ⅓ of its initial potential, the gold-coated fiber touches and recharges the collector. The electrical pulse so obtained is amplified and results in a transmitted pulse, which is picked up by a receiver on the ground. Barometric and temperature data are also transmitted. The calibration of the ion chamber thus should remain constant with time, provided the following do not change: (1) the quartz fiber, (2) the geometry of the system, and (3) the pressure of the enclosed argon. The ion chamber has a diameter of 25 cm and gives an accuracy of ±0.3 percent for each discharge for β-particles. The whole equipment weighs 2 kg.

* Supported in part by the joint program of the ONR and AEC.

A4. Large Ionization Bursts at High Altitude.* R. F. CHRISTY, A. T. BIEHL, E. INONU, AND H. V. NEHER, *California Institute of Technology.*—Extended airplane flights at 30,000 feet in recent years by two of the authors have shown a significant number of bursts of more than 400 fast particles as recorded by a 10-atmosphere argon-filled ionization chamber shielded by 10 cm Pb. In addition, similar data had been obtained previously with the same equipment at 14,500 feet and at sea level. The sea level data are consistent with those obtained by other investigators with similar equipment and are accounted for by the bremsstrahlung of μ-mesons in the lead shield. The two high altitude points, on the other hand, show a large increase with altitude consistent with an exponential length of ~130 gm of air and demand a different explanation. As Rossi has pointed out, they can be understood in terms of the production in the Pb shield, by the primaries, of neutral mesons which lead to cascade bursts by their decay γ-rays. The primary energies associated with these events are $\sim 10^{11}$ ev. Preliminary calculations show that it is possible to correlate numerically the number of such primaries with the number of bursts. More detailed calculations are in progress to reveal more about the number and spectrum of these primaries.

* This work was assisted by the joint program of the ONR and AEC.

Invited Papers

A5. Unstable Particles in Penetrating Cosmic Ray Showers. E. W. COWAN, *California Insitute of Technology.* (30 min.)

A6. The Nature of the π-Meson. ROBERT SERBER, *University of California, Berkeley.* (30 min.)

THURSDAY MORNING AT 10:00

Room 45, Chemistry Building

(A. BAÑOS, JR., presiding)

Contributed Papers

B1. Corona in H_2 with Coaxial Cylinders. EUGENE J. LAUER, *University of California, Berkeley.*—Corona in pure H_2 and in H_2 with a small amount of N_2 or O_2 has been studied with the same system as used by C. G. Miller.[1] Positive wire corona in pure H_2 started with burst corona. Weissler observed no bursts in point-to-plane corona in pure H_2. This difference can be explained by the longer high field region along the wire allowing photoionization. Negative wire corona started at lower potential than the positive. There was a marked overshoot in onset which decreased in relative amount with decreasing pressure. The negative corona started as an invisible self-supporting discharge with a current several powers of ten smaller than that of the visible corona of microamperes current. In time, or upon small increase of potential, the small current changed suddenly to the large (microamperes) current discharge at conditioned spots on the wire. The addition of 0.1 percent of N_2 or O_2 to the H_2 resulted in pre-onset streamers from the positive wire. O_2 lowered the positive wire onset and raised the negative wire onset. N_2 had no marked effect on the onsets.

[1] Charles G. Miller, Phys. Rev. **75**, 1460 (1949).

B2. Corona from Ice Points. H. W. BANDEL,* *University of California, Berkeley.*—In connection with questions on atmospheric electricity some work has been done with corona from ice points using point-to-plane geometry. One- and two-mm diameter ice points were used with an 8-cm gap at $-78°C$ and $-10°C$ and compared with platinum points under the same conditions. With 1-mm points currents rose with voltage from low values of around 10^{-13} amp up to values, at well above onset voltage, of 10^{-11} amp with distilled water ice and 10^{-9} to 10^{-8} amp with tap water ice compared to 10^{-6} amp with platinum points. These relative magnitudes are in line with measured resistances of 10^{11} to 10^{13} ohms for tap water and 10^{14} ohms for distilled water ice points. Corona onsets occurred at roughly the same voltages as for metal points; but the burst pulses, streamers, and Trichel pulses characteristic of positive and negative metal point corona were not observed, although the oscilloscope showed random, low amplitude pulses with time duration of milliseconds for both polarities. Thus far it seems doubtful that ice crystals can lead to premature spark breakdown or to lightning discharge at lower potentials in air owing to the low currents passed.

* Supported by ONR funds.

B3. Principle of Similitude. L. B. LOEB AND E. E. DODD,* *University of California, Berkeley.*—In this country investigators of gaseous discharges have generally ignored the principle of simultude of Holm[1] and Steenbeck.[2] This is apparently due either to lack of familiarity with the principle, since it has not been presented completely in English, or to lack of confidence in it. For this reason the complete principle is presented and discussed. It is concluded that its best use today is as a check for theories of individual discharge mechanisms.

* Supported by ONR funds.
[1] Holm, Physik. Z. **25**, 504 (1924).
[2] Steenbeck, Wiss. Veröffenbl. Siemens-Konzern **11**, No. 2, 36 (1932).

B4. Spray Electrification of Liquid Drops. E. E. DODD,* *University of California, Berkeley.*—The simultaneous size and charge of many individual drops of various liquid sprays are being determined by the Hopper and Laby method. This data will be useful in resolving the present uncertainties concerning the effects of the various possible spray electrification mechanisms.[1] The apparatus built and described by Kunkel and Hansen[2] is being used with low vapor pressure liquids having varying physical properties. Drop diameters in a range of about 2 to 30 microns and with charge to diameter ratios up to about 500 electrons per micron can be measured. Observations made of more than 6000 drops produced by atomization indicate that the numbers of positively and negatively charged drops of poorly conducting liquids are roughly equal, as are their average charges, while drops of conducting liquids are predominately positively charged. Sample data are presented to illustrate the rather broad distribution in charge for a particular drop size and the variation of average charge per drop with drop size and physical properties of the liquid.

* Supported by ONR funds.
[1] Loeb, Science **102**, 573 (1945).
[2] W. B. Kunkel and J. W. Hansen, Rev. Sci. Inst. **21**, 308 (1950).

THURSDAY AFTERNOON AT 2:00

Room 19, Chemistry Building

(E. L. KINSEY presiding)

Contributed Papers

C1. Stars in Photographic Emulsions Initiated by Protons.* LAWRENCE S. GERMAIN, *University of California, Berkeley.*—A study has been made of stars in photographic emulsions initiated by protons from the 184-inch Berkeley cyclotron. Ilford G-5 electron sensitive plates were exposed to the proton beam with the emulsion parallel to the beam. A workable exposure, about 20 proton tracks per 100-micron field of view, was obtained by dropping the plates through the deflected proton beam of the cyclotron. Energies as low as 95 Mev were obtained by placing Al absorbers in front of the plates. The plates were scanned for all stars initiated by the protons, and the total length of proton track was found by examining sample areas. The average number of prongs per star and the cross section for production of stars of two or more prongs was calculated for various energies between 95 Mev and 340 Mev. Both of these quantities increased with increasing energy up

to the highest energy used. At 340 Mev the cross section was found to be 0.29 barn, while the average number of prongs per star was 3.9.

* This work was done under the auspices of the AEC. Work done at Reed College was assisted by a Research Corporation grant.

C2. Delayed Emission of Neutrons from Light Elements.* WILLIAM GARDNER, N. KNABLE, AND B. J. MOYER, *University of California, Berkeley.*—In addition to the delayed neutrons appearing with a 4.17-sec half-life from the decay of N^{17} previously identified at Berkeley, a 0.165-sec emission has been discovered. It has been obtained, at the time of this writing, by 190-Mev deuteron bombardment of Be_2N_3 and elemental boron. Observations are made by rapidly moving film exposures of an oscilloscope screen displaying a scaled output of BF_3 chamber pulses. The target under bombardment is surrounded by the chamber. The results of attempts to identify the neutron emitter and the parent β-decay will be presented.

* This work was performed under the auspices of the AEC.

C3. Photo Production of Neutral Mesons from Hydrogen.* J. S. STELLER AND W. K. H. PANOFSKY, *University of California, Berkeley.*—The work of Steinberger, *et al.*,[1] on the production of neutral mesons by photons from the Berkeley synchrotron has been extended using liquid hydrogen as target. Liquid scintillators (0.5 percent terphenyl in xylene) in sealed glass containers arranged as described in reference 1, were used to detect the decay gamma-rays. The experimental set-up permits measurement of both meson production angle and correlation angle between the decay gamma-rays. The correlation angle is a calculable function of the π^0-energy; therefore, the measured distribution limits the choice of π^0-energy distribution to a considerable extent. Here, the recoil nucleus is known to be a proton, so that one can calculate the incident photon energy and hence deduce the energy dependence of the production cross section. This is definitely a more rapidly rising function than the excitation function of photo production of charged mesons.[2] A value for the total cross section of 1×10^{-28} cm^2 per effective quantum is observed, in good agreement with the previously reported value from carbon-paraffin difference. Photo production cross section for charged and neutral mesons in hydrogen for 320-Mev bremsstrahlung are thus essentially equal. Work is continuing on the angular distribution of the π^0's.

* This work was performed under the auspices of the AEC.
[1] J. Steinberger, W. Panofsky, and J. Steller, Phys. Rev. **78**, 802 (1950).
[2] J. Steinberger and A. Bishop, Phys. Rev. **78**, 493 (1950).

C4. Grain Density Measurements in Nuclear Emulsions.* J. KENT BOWKER, JOHN R. GREEN,† AND WALTER H. BARKAS, *University of California, Berkeley.*—The validity of the relation $dN/dR=f(dE/dR)$ has been studied for high energy charged particles. N is the number of grains in a residual range R, and E is the kinetic energy of the moving particle. From grain counts of mesons, protons, and alpha particles it is found that the grain density does not depend explicitly on the charge of the moving particle, but to good approximation just on its rate of energy loss. It is found also that when dN/dR is small, it becomes proportional to dE/dR. A saturation effect exists because only a finite density of potentially developable grains are threaded by the moving particle, so dN/dR cannot rise in proportion to dE/dR as the particle slows down. By measuring the gap density, $g(R)$, in clogged tracks, one may determine the probability of grains *not* being rendered developable. A relation $G/M=F(R/M)$ holds for particles of the same charge, where $G(R)=\int_0^R g(R)dR$. Measurements on the "integrated emptiness" of tracks demonstrate that in the region where grain counting fails because of clogging, gap measurements provide reliable mass ratios.

* This work was performed under the auspices of the AEC.
† Now at the University of New Mexico, Albuquerque, New Mexico.

C5. Protons Scattered out of Nuclei at High Energies.* J. B. CLADIS, J. W. HADLEY, AND B. J. MOYER, *University of California, Berkeley.*—Proton energy spectra are obtained by deflecting scattered protons by a magnetic field into channels defined by proportional counters and a bank of 35 Geiger counters. With incident protons of 340 Mev, the scattered protons from light elements viewed at 22° have spectra resembling free particle scattering: the peaks fall at nearly the same energy, the deuterium yield is about twice the hydrogen yield, and the carbon points multiplied by 16/12 give a curve which is indistinguishable from that of oxygen. With incident neutrons of 270 Mev on deuterium, scattered proton yields in the forward direction are suppressed relative to corresponding yields from hydrogen. This is in keeping with predictions based on exclusion principle requirements pertaining to the two neutrons which now possess a small relative momentum.

* This work was sponsored by the AEC.

C6. Angular Distribution of Gammas in Showers.* JACK W. ROSE, *University of California, Berkeley.* A study has been made of the angular distribution of gammas in showers initiated in lead and copper by the 335-Mev bremsstrahlung of the Berkeley synchrotron. The x-ray beam, collimated to $\frac{1}{4}$ inch, passed normally through a thin monitor foil and then through plates of lead or copper. The shower gammas emerging from the far side of the plates were detected by means of the radioactivity of copper foils, by means of the reaction $Cu^{63}(\gamma, n)Cu^{62}$. The activities induced in the foils at various angles with the beam were compared to that in the monitor foil by means of G-M counters. Since the (γ, n) reaction utilized is believed to have a narrow excitation curve peaked at about 20 Mev,[1] the angular distribution curves obtained should be essentially those for 20-Mev gamma-rays. The preliminary results agree reasonably well with calculations of the lateral structure of showers to be published by L. Eyges and S. Fernbach.

* This work was sponsored by the AEC.
[1] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **73**, 1156 (1948).

C7. Large Angle Scattering and Stars Produced by π^- Mesons in Flight.* HUGH BRADNER AND BAYARD RANKIN, *University of California, Berkeley.*—An investigation is being made of the scattering of energetic π^- mesons in photographic emulsion. Mesons of approximately 38 Mev are obtained by a channel inside the Berkeley cyclotron. These mesons traverse G-5 emulsion. Four-hundred- and 600-micron thick emulsions are placed with their surfaces parallel to the meson beam, so that individual meson tracks can be followed. Mesons are differentiated from protons by their grain density and small angle Coulomb scattering in the first 500 microns of observed track. μ-meson background is determined by observing tracks in a second set of emulsions placed beyond the range of the π^- mesons. Scatters between 5° and 25° are in agreement with single Coulomb scattering. 26 scatters of total angle greater than 30° and 11 stars have been observed in a total length of 902 cm of π^- track. Five mesons were seen to disappear in flight. The latter events may be attributed to the reaction π^-+p, π^0+n, or to "stars" with only neutrons emitted. The mean free paths for large angle scatters, stars, and total nuclear interactions are, respectively: 34.7 ± 4.6, 82.0 ± 16.7, 21.5 ± 2.2. Nuclear area of the elements of the emulsion corresponds to approximately 23-cm mean free path. Hence, it appears that the total cross section for nuclear interaction of 30–40-Mev π^- mesons in emulsion is equal to nuclear area.

* This work was performed under the auspices of the AEC.

C8. Proton-Proton Scattering at 75 Mev and 100 Mev.* ROBERT W. BIRGE† AND ULRICH E. KRUSE, *Harvard University.* The angular distribution of the proton-proton differential scattering cross section has been measured using the

Harvard 95-inch cyclotron.[1] The internal beam was intercepted by a ten-mil polyethylene foil. Protons scattered in the vertical plane were counted by scintillation crystals placed above and below the median plane. The C^{11} activity induced in the target was counted at the end of each five-minute run to serve as a monitor for the beam current and to give a rough value for the absolute scattering cross section. To obtain the 75-Mev incident protons, the target was moved inward radially from 40 inches to 35 inches and the counting probes lengthened accordingly. Complete results of the 100-Mev experiment and preliminary results of the 75-Mev experiment will be presented.

* Assisted by the joint program of the ONR and AEC.
† Now at the University of California Radiation Laboratory.
[1] R. W. Birge, Phys. Rev., to be published.

C9. Fast Protons from π^- Meson Absorptions in Photographic Emulsions.* F. L. ADELMAN, *University of California Berkeley.*—The spectrum of fast protons from 1631 π^- meson absorptions in Ilford G-5 and C-2 emulsions has been studied. Protons of energy >30 Mev were found to accompany (9.5±1.3) percent of all π^- absorptions, in agreement with other workers.[1,2] The proton energies were estimated by grain-counting in comparison with π^- mesons of known residual range. Allowance was made for variation of grain density with position and depth in the emulsion. The energy spectrum is fairly flat from 30–70 Mev, but only three events were found above 70 Mev. Examination of stars from which the fast protons were emitted shows more prongs ejected opposite to the direction of the fast proton than are accounted for by evaporation from a recoiling nucleus. The evidence suggests that the meson is captured by a proton, and that the resultant neutron recoils against a small, variable number of nucleons; the low energy star prongs apparently result from knock-on collisions of these nucleons with other nucleons inside the nucleus. Comparison is made between other theories and the experimental results.

* This work was sponsored by the AEC.
[1] W. Cheston and L. Goldfarb, Phys. Rev. **78**, 683 (1950).
[2] M. Menon, H. Muirhead, and O. Rochet, Phil. Mag. **41**, 583 (1950).

Invited Papers

C10. Current Research in Physics at the University of Utah. L. B. LINFORD, *University of Utah.* (30 min.)

C11. Nitrogen Absorption Coefficients in the Vacuum Ultraviolet, and Related Problems. G. L. WEISSLER, *University of Southern California.* (30 min.)

THURSDAY AFTERNOON AT 2:00

Room 45, Chemistry Building

(J. W. ELLIS presiding)

D1. Static and Dynamic Current-Voltage Characteristics of Glow Discharges. DAVID L. FAYMAN AND CHARLES G. MILLER, *University of California, Santa Barbara.*—The current-voltage characteristics of various electrode shapes and gases have been investigated, and a report is made of the voltage-regulating action and of some dynamic characteristics of glow discharges. In the case of positive-wire, concentric cylinder geometry, the use of diatomic, non-electron-attaching gases (H_2 and N_2), provide stable, high voltage voltage-regulator tubes. Certain electron-attaching polyatomic gases may also be used in particular geometries. In the case of negative wire systems, highly purified N_2 enables very high voltage voltage-regulator tubes to be realized. The role of the electron attaching impurities evolved from the electrodes is discussed. The dynamic characteristics of glow discharges are described in the range 60 cps to 30 kc/s for rare gases, for N_2 and for H_2. A hysteresis effect and a negative resistance region are found for the gases studied, and the manner in which these affect circuit designs are discussed.

D2. Positive and Negative Corona in Oxygen, in Freon, and in Mixtures. CHARLES G. MILLER AND DAVID L. FAYMAN, *University of California, Santa Barbara.*—Dc corona studies have been carried out in oxygen, in freon, and in mixtures using concentric cylindrical geometry, affording a comparison with the work of Weissler and Mohr[1] who used point-to-plane geometry and freon-air mixtures. In the present experiments using positive corona, the discharge in pure oxygen gives streamers at high pressures, burst pulses at low pressures. The addition of freon allows streamers at all pressures. In the case of the negative corona, in oxygen and in freon small patches of the cathode are cleaned by the action of the positive ions bombardment; and the current is then limited by the action of Trichel pulses.[2] The discharge in oxygen begins as a *general* glow, which disappears when the Trichel pulses and the Trichel pulse spots appear, while the current jump at onset is only slight for atmospheric pressure oxygen. As the pressure is lowered, the overshoot in voltage is more pronounced since a cleaned spot can be more easily maintained.

[1] G. L. Weissler and E. I. Mohr, Phys. Rev. **72**, 289, 294 (1947).
[2] Loeb, Kip, Hudson, and Bennett, Phys. Rev. **60**, 714 (1941).

D3. Pulse-Annealing for the Study of Relaxation Processes in Solids.* W. E. PARKINS AND G. J. DIENES, *North American Aviation, Inc.*—A "pulse-annealing" method has been developed for heating small samples of electrically conducting solids to chosen elevated temperatures for short periods. After each annealing pulse a physical property determination is made on the sample at a fixed reference temperature. From this record of the physical property changes resulting from successive annealing pulses, much can be learned of the nature of relaxation processes occurring within the solid. Types of lattice processes which can be studied include impurity diffusion, recrystallization, chemical reaction, and various types of phase changes. Activation energies for individual states can be accurately determined without any knowledge of the dependence of the physical property on the amount of lattice relaxation. In order to establish the rate constant and reaction order associated with the relaxation kinetics this property dependence must be known. For the pulse-annealing schedule it is sometimes advisable to obtain isothermal annealing results by repeated pulsing to some given temperature. In other cases annealing pulses are made to successively higher temperatures thereby simulating tempering treatment. Apparatus will be

described which has been used to measure electric resistivity changes in graphite and in metal samples. Typical experimental results will be given.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

D4. Kinetics of Ordering in the Alloy AuCu.* G. J. DIENES, *North American Aviation, Inc.* (introduced by M. M. Mills).—The kinetics of ordering in AuCu has been studied using electrical resistivity as the index of order. A purely phenomenological analysis of isothermal resistivity-time curves showed that ordering in this alloy is a process characterized by a single constant activation energy of 29 Kcal. For further kinetic analysis it is necessary to transform the raw data into isothermal order parameter-time curves. This was accomplished via a semi-theoretical relation between resistivity and the average degree of short range order (σ) and substantiated by agreement with available experimental information. A consistent kinetic picture was obtained in terms of σ with the ordering process accurately described by a simple third-order rate equation with all the kinetic constants fully evaluated. The usual ln (rate constant) *vs.* $1/T$ plot gave an activation energy of 28.5 Kcal, in excellent agreement with the phenomenological activation energy. Further experiments showed that the proposed kinetics predicts correctly the response to complex time-temperature sequences. Some of the uncertainties arising in the analysis are pointed out. Future work, designed to elucidate the disordering kinetics, and thereby the equilibrium degree of order-temperature relation, will be briefly discussed.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

D5. Singlet-Triplet Absorption Bands in Some Organic Molecules.* D. S. MCCLURE, N. BLAKE, AND P. HANST, *University of California, Berkeley.*—Singlet-triplet bands have been observed for several organic compounds in solution at room temperature and at 77°K. The absorption spectra at 77° are the first observations of absorption to the triplet state under the same conditions of temperature and medium at which the emission spectra have been observed. The low temperature work, using a meter path length, makes possible the resolution of S−T transitions which are not resolved at room temperature, and further allows the location of triplet levels for those molecules which have little or no T−S emission.

* Sponsored, in part, by the ONR.

D6. The Quantum Yields of Fluorescence and Phosphorescence of Some Organic Compounds. E. H. GILMORE* AND D. S. MCCLURE, *University of California, Berkeley.*—The quantum yields of phosphorescence and fluorescence have been determined for several organic compounds maintained in a rigid glass medium at 77°K. This work was undertaken as a supplement to the work of D. S. McClure,[1] who determined the emission decay lifetimes of the phosphorescence (triplet) levels of these compounds, and who further postulated a theory to explain these lifetimes. An accurate check of the the theory requires true electronic transition probabilities for the phosphorescence to ground level transition. These are obtained in the relation $\frac{\nu}{TG} = Q_P/\tau_0(1-Q_F)$, where $\frac{\nu}{TG}$ is the phosphorescence to ground level electronic transition probability, Q_P is the phosphorescence quantum yield, Q_F is the fluorescence quantum yield, and τ_0 is the emission decay lifetime (mean life). Quantum yield measurements were undertaken for nine compounds. Six had total quantum yields in excess of ten percent, and the remaining three were five percent or less. An indication of the explanation of the marked difference in aliphatic and aromatic ketone phosphorescence lifetimes is found in the quantum yield results. The aromatic hydrocarbons examined have very nearly the same transition probability value. Should this be true for aromatic hydrocarbons in general, it would appear that an identical mechanism is responsible for the transition in the entire class of compounds.

* Present address: U. S. Naval Ordnance Test Station.
[1] D. S. McClure, J. Chem. Phys. **17**, 905–13 (1949).

D7. Aging of $BaTiO_3$ Ceramics. W. R. EUBANK AND L. E. SCHILBERG, *U. S. Naval Ordnance Test Station* (introduced by H. W. HUNTER).—For the purpose of exploring the aging of $BaTiO_3$ ceramics in great detail, with special reference to dielectric properties, approximately twenty-five specimens have been made (by various techniques) and studied during thermal cycling (50°C–140°C). The curves for dielectric constant *versus* temperature for specimens made of spectrographic grade materials were of the shape customarily reported in the literature, while those for specimens of reagent grade were much more rounded and had somewhat lower peak values. In general, both types of specimens showed progressive aging corresponding to a lowering dielectric constant, the effect being much more pronounced in those of spectrographic materials than in those of reagent grade. Although sufficient data are not yet available to allow correlations with known factors (as of methods of preparation), it is felt that the aging in $BaTiO_3$ ceramics may be so violent in some cases as to warrant this report in emphasis of the phenomenon.

D8. Effects of Thin Films of Silver and of Gas at the Surface of the (100) Face of a Silver Crystal.* H. E. FARNSWORTH AND EDWARD N. CLARKE,† *Brown University.*—Observations on a silver crystal in a single photoelectric and low speed electron diffraction tube, combined with observations previously obtained, indicate the following for silver: (1) Intensities of low energy diffraction beams (below 50 ev) are influenced primarily by the surface monolayer of atoms, while the surface photoelectric work function, φ, is determined by a volume layer more than one atom thick. This makes it possible to distinguish between true surface effects and those of thin layers just beneath the surface. (2) φ for silver increases as gas in the volume layer decreases. (3) Rapid deposition of doubly-distilled silver in high vacuum can form a clean surface as determined by electron diffraction. This deposited layer can cover a gas contaminated surface, at least for a limited time. (4) The silver film forms as a single crystal on the surface of a silver crystal and causes a decrease in φ. This decrease depends on (a) value of φ before deposit, (b) temperature of the crystal during deposition. It does not depend on (a) rate of deposition, (b) amount of silver deposited (within limits), (c) residual gas pressure in the range 10^{-8} to 10^{-6} mm Hg. (5) Low temperature heating (less than 75°C) of the silver film on bulk silver causes φ to increase. Significance of the above observations will be discussed.

* Assisted by the ONR and Research Corporation of New York.
† Socony Vacuum predoctoral fellow.

D9. Activation of a Solid Nickel Catalyst for the Hydrogenation of Ethylene by Heat Treatment in a High Vacuum.* R. K. SHERBURNE† AND H. E. FARNSWORTH, *Brown University.*—These results are preliminary to an investigation of the catalytic activities of individual faces of metal single crystals. A Nier-type mass spectrometer is used to analyze the products of the reaction. The nickel specimen, in the form of a sheet 15 mm diameter by 0.25 mm thickness, was cleaned, and electrolytically polished to produce a smooth surface free of points. It was outgassed in an evacuated reaction chamber by high frequency induction, with the residual air pressure successively at 10^{-4}, 10^{-5}, 2×10^{-7} mm Hg. After each outgassing equal volumes of hydrogen and ethylene were admitted to the reaction chamber, maintained at 135°C, at total pressures between 6 and 16 mm Hg. Subsequently,

samples of the resulting gas were analyzed in the mass spectrometer after various time intervals. The activity increased with decrease in residual air pressure during outgassing, and with increase of time of outgassing at dull red heat temperatures. Many hours of heat treatment at 400°C produced only a negligible amount of activity. Exposure of the active specimen to low residual air pressures for several hours reduced its activity, thus indicating that small amounts of adsorbed gas are sufficient to poison the active surface for the reaction in question.

* Assisted by the ONR and Research Corporation of New York.
† Now at New Mexico College of Agriculture and Mechanic Arts.

FRIDAY MORNING AT 9:00

Room 19, Chemistry Building

(R. T. BIRGE presiding)

Contributed Papers

E1. Decay Scheme of Mo^{99}. H. MEDICUS,* D. MAEDER, AND H. SCHNEIDER,† *Swiss Federal Institute of Technology, Zürich.*—β-decay of Mo^{99} proceeds in practically all cases by way of excited levels in Tc^{99}. About 87 percent of the transitions ($\beta_{max}=1.225\pm0.015$ Mev) lead to the well-known isomeric level of Tc with 6 hours half-life[1] which lies 143 kev above the ground state. This will be reached by a cascade consisting of a highly converted 1.8 ± 0.3-kev transition (to which the isomeric behavior is to be attributed) and of a γ-ray of 141.2 ± 0.5-kev energy of low multipole order (conversion coefficient $\alpha=0.095\pm0.020$, $\alpha_K:\alpha_L:\alpha_{M+N}=(7.9\pm0.5):1:(0.30\pm0.03)$). About 13 percent of the transitions of Mo^{99} lead to an excited Tc level of 969 kev. Thence the 141.2-kev level is reached directly by emission of a 728 ± 8-kev γ-ray, whereupon transition to the ground state follows. Very weak γ-rays were also found with energies of 182 ± 3 and 360 ± 6 kev. The expected β-transition from isomeric Tc^{99} to the ground state of Ru^{99} could not be observed. Its probability must therefore be smaller than that of the isomeric transition by a factor of 3.10^{-4}.

* Present address: Radiation Laboratory, University of California, Berkeley.
† This work was performed under the auspices of the AEC.
[1] G. T. Seaborg and E. Segrè, Phys. Rev. **55**, 808 (1939).

E2. Relative Photo-Neutron Yields from the 330-Mev Bremsstrahlung.* W. N. JARMIE, L. W. JONES, AND K. M. TERWILLIGER, *University of California, Berkeley.*—Relative photo-neutron yields were determined for 50 elements bombarded by the 330-Mev x-ray bremsstrahlung of the Berkeley synchrotron. The determinations were made at 90° to the beam axis with a BF_3 proportional counter surrounded by a paraffin moderator. Paraffin-cadmium shielding reduced the neutron background to less than 30 percent of the target yield for all but five targets, and to 4 percent for the heaviest elements. Statistical counting errors were kept below 3 percent. Absolute yields per unit beam energy were determined using calibrated Ra–Be and Po–Be sources and the beam energy measurements of Blocker and Kenney. Relative yields for high Z elements lie on a smooth curve and are in approximate agreement with Kerst. Deviations from a smooth curve for yields from low Z elements will be discussed. Angular distributions of photo-neutrons were briefly investigated, and a Pb transition curve for photo-neutrons was run.

* This work was performed under the auspices of the AEC.

E3. Angular Distribution of Neutrons from 20-Mev Deuterons. L. SCHECTER,* *University of California, Berkeley.*—The spatial distribution of neutrons produced by the impact of deuterons of maximum energy 20 Mev on various thick targets has been investigated, using the 60-inch cyclotron at the Crocker Laboratory. The neutrons in the energy regions above 20 Mev, 11 Mev, and 5 Mev were detected by the resulting β-activities induced in C, Cu, and Be, Al, Cu, Sn, Pb, and U. The distributions vary in a nonregular way from element to element, the characteristic features being the width at half-maximum, and the angular position of the maximum. Among the elements investigated, Be and Cu yield neutrons, which, above 20 Mev, have their spatial maximum displaced from the direction of the incident deuteron beam. At lower energies, this apparent "double peak" is washed out, indicating that the distributions result from the superpositions of several different nuclear processes of comparable importance. This is to be compared to the distributions resulting from 190-Mev deuteron impacts, which agree quantitatively with the single process of stripping.

* This work was performed under the auspices of the AEC.

E4. Multiple Traversals of High Energy Particles in a Cyclotron Beam through Thin Targets. W. J. KNOX,* *University of California, Berkeley.*—An experimental determination has been made of the average numbers of times that 340-Mev protons traverse various targets in the Berkeley 184-inch cyclotron. The numbers range from slightly above 1 for a 1-inch thick copper target to about 15 for an aluminum target 0.0015 inch thick. The results are compared with calculated values based on multiple scattering in the target and oscillations of the particles in the cyclotron. It is believed that the results can be adapted to apply to various particles of different energies in the cyclotron. Calculations are made on the energy distribution of beam particles which cause reactions in a target and distributions are shown for several targets. The selection of targets for the production of high energy neutron beams is discussed. Histograms are presented showing the depth of radial penetration of the 340-Mev proton beam into various targets.

* This work was performed under the auspices of the AEC.

E5. The Production of π^+ Mesons by Protons on Protons in the Direction of the Beam.* W. F. CARTWRIGHT, C. RICHMAN, M. H. WHITEHEAD, AND H. A. WILCOX, *University of California, Berkeley.*—The first measurements of the cross sections for π^+ meson production by proton-proton collisions showed a large peak in the energy spectrum near the maximum energy of the mesons.[1,2] To determine more accurately the spectrum in the region of the peak for mesons produced at zero degrees we have modified our original detection arrangement. By using a new magnet with a larger gap and bending the meson trajectories further away from the proton beam, we have decreased the background due to other particles and obtained better statistics. The proton beam energy fluctuations are minimized. With these improvements the peak has been in-

vestigated in detail. Two reactions may occur: (1) $p+p\rightarrow\pi^{+}+d$ and (2) $p+p\rightarrow\pi^{+}+n+p$. Mesons produced in (1) in the laboratory system have an energy four Mev higher than the maximum energy of those produced in (2). The measured values of the maximum meson energy and the proton beam energy indicate that if the meson mass is 276 electron masses, deuteron formation does take place. The peak in the spectrum is centered at 70 Mev and has a half-width of about 4 Mev.

* This work was performed under the auspices of the AEC.
[1] Cartwright, Richman, Whitehead, Wilcox, Phys. Rev. **78**, 823 (1950).
[2] Peterson, Phys. Rev. **79**, 407 (1950).

E6. Covariant Description of a Bound State. D. L. DRUKEY*† AND J. W. WEINBERG, *University of Minnesota.*—The description of a bound state is formulated in interaction representation using plane wave normal modes. For this, an invariant counting technique is devised. Approximate forms of the "interaction Hamiltonian" and the resulting energy-momentum four-vector operators are obtained from a particular coupling model by application of perturbation theory and the correspondence limit. The "Schrödinger equation" takes the form of an eigenvalue equation, $P_{\mu}\Psi=p_{\mu}\Psi$, where P_{μ} and p_{μ} are, respectively, operator and eigenvalue, and Ψ is the state functional. In order that the P_{μ} commute, it proves necessary that the space-like surfaces over which Ψ is defined be hyperplanes. This restriction does not destroy the covariance of the formalism, however. Solution of the Schrödinger equation may be effected by reducing from second to primary quantized form. This yields a set of integral equations with the energy and momentum of the compound system as eigenvalues. Equations for the deuteron will be presented.

* Now at the Radiation Laboratory, University of California, Berkeley, California.
† Part of this work was performed under an AEC Fellowship.

E7. Large Angle Focusing of π^{+} and π^{-} Mesons.* R. SAGANE AND PETER C. GILES, *University of California, Berkeley.*—A test has been carried out to focus mesons with the use of the Spiral Orbit Spectrometer principle[1] (2π angular focusing of charged particles originated from the axis with the use of an axial symmetric heterogeneous magnetic field). Meson density of more than 10/sec/cm^{3} of nearly homogeneous energy mesons has been obtained so far with 10^{-12} amp of protons at 345 Mev. Nuclear emulsion has been used to detect these focused mesons. Both thick and thin targets made of several different elements were used with and without an axial symmetric Cu tubular absorber. A study of the π^{+}/π^{-} ratio of a low (10-Mev) and a high (40-Mev) energy region of mesons from Al, Cu, Ag, Sn, and Pb is now going on. Focusing conditions are quite symmetric for mesons of both signs. Positive and negative mesons coming from opposite directions are stopped in the same portion of a stripped emulsion by using wedge absorbers on each side of the emulsion. An attempt to count the positrons from the decay of μ^{+} mesons stopping in the target is being made with the same focusing arrangement.

* This work was performed under the auspices of the AEC.
[1] G. Miyamoto, Proc. Phys.-Math. Soc. Japan **17**, 587 (1943); M. Sakai, J. Phys. Soc. Japan **5**, 178–187 (1950).

Invited Papers

E8. The Inter-University High Altitude Laboratory and Atmospheric Research. B. E. COHN, *University of Denver.* (30 min.)
E9. High Altitude Solar Studies. W. B. PIETENPOL, *University of Colorado.* (30 min.)

FRIDAY MORNING AT 9:00

Room 45, Chemistry Building

(R. E. HOLZER presiding)

Contributed Papers

F1. Instrumentation for High Altitude Infrared Solar Measurements.* ROMUALD ANTHONY, *U. S. Naval Ordnance Test Station* (introduced by E. V. Ashburn).—In order to obtain solar infrared spectra in the 1 to 25 micron region at high altitudes, a potassium bromide double monochromator ordinarily used in the laboratory was installed in a B-29 aircraft. The behavior of the aircraft in flight and the delicate nature of the monochromator determined the design of the accessory apparatus. The monochromator was suspended in a cradle. The cradle was a portable structure containing all the reflecting optics necessary to direct the solar radiation received from the heliostat and focus it on the entrance slit of the monochromator. Approximately 25 minutes was required to scan the spectrum; therefore, a simple photo-cell heliostat was constructed to compensate for roll, yaw, and pitch of the aircraft as well as the motion of the sun in the sky. The heliostat, which could be operated manually, was an "off-on" dc system that controlled the direction of the incoming solar radiation by responding to the displacement of a solar image relative to four photo-cells. It performed the task of maintaining the solar image on the slit to ±2 mils during flight. Considerable variation in temperature was expected with change in altitude; therefore, an electric blanket was built to cover the monochromator and keep it at constant temperature. The total temperature change during flight did not exceed 2°F.

* Program supported by the ONR and in collaboration with Johns Hopkins University.

F2. The Density of the Upper Atmosphere and the Intensity of the Zenith Sky Light during Twilight.* EDWARD V. ASHBURN, *U. S. Naval Ordnance Test Station.*—An improved numerical treatment of the application of the Rayleigh scattering law to the atmosphere during twilight has been developed. This new treatment, combined with new measurements of the intensity and polarization of the zenith sky light has led to a determination of the density of the atmosphere to a height of 120 km. The results are in agreement with the U. S. Tentative Standard Atmosphere of the N.A.C.A.

* This work supported by the ONR.

F3. Aerosol Particle Size Studies using Natural Radioactivity as a Tracer. M. H. WILKENING, *New Mexico School of Mines, Socorro, New Mexico.*—Apparatus has been built

which (1) ionizes aerosol particles in an incoming air stream, (2) separates the resulting ions according to their mobilities, and (3) deposits them on a collecting surface. One can then study this distribution by means of the natural radon disintegration products which are present in an aerosol particle collection. The collection is on the outer electrode of a cylindrical condenser carrying an axial air stream, the ion-bearing air being introduced in a layer around the inner electrode. The distribution of radioactivity along the outer electrode is determined by a grid-type proportional counter. Knowing the air flow, the electric field and the geometry of the condenser, a value can be computed for the mobility of the ions deposited on any section of the electrode. The mobility is correlated with particle size by use of Stokes' Law with the Cunningham correction. Preliminary results indicate that most of the natural radioactivity in the atmosphere resides on particles in the size range 0.001 to 0.03 micron and that particles in this size range are far more abundant than larger ones.

F4. Boundary-Value Problems of Transverse Waves. WALTER M. ELSASSER,* *University of Utah.*—In textbooks of electrodynamics there are described transverse (nondivergent) solutions of the vector wave equation. The components of each such wave are expressions containing one corresponding solution of the scalar wave equation and its derivatives. We have studied the boundary conditions for which these transverse waves form a complete orthogonal set over a suitable finite domain. We find such sets to exist for only two types: Plane waves with cyclic boundary conditions in Cartesians, and spherical waves with some simple linear boundary conditions at a spherical surface. Even for a cylinder of finite cross section and either infinite or finite length, orthogonality of the "natural" set of cylindrical transverse waves cannot be achieved solely by the application of linear boundary conditions. Thus, it seems that the Sturm-Liouville scheme, so successful for scalar waves, is really of little avail for transverse waves, and new mathematical methods ought to be developed to deal with them and their physical applications.

* Supported by Contract N-7-ONR-388 with the Institute for Advanced Study in Princeton.

F5. A Magnetic Suspension for Vertical Seismometers. C. R. HOLMES AND E. J. WORKMAN, *New Mexico School of Mines.*—In any seismological problem where it is desirable to record low frequency oscillations with a displacement meter, the main difficulty is to obtain reliable spring suspensions having a sufficiently long period. The nonlinear properties that result from the conventional use of springs are discussed. The authors have devised an electromagnetic suspension which eliminates many of these disadvantages. A cylindrical coil which is constrained to move along its vertical axis intercepts a radial magnetic field in such a way that the mass is supported with a "spring" stiffness factor which can be made small enough so that the sprung mass is in effect a free inertia mass. The net forces acting upon the mass thus supported may be adjusted by a variety of methods in order to give the desired characteristics of oscillation. The pick up may be a second coil acting on the same magnetic field, or a second magnetic field, or a number of displacement or velocity measuring devices, some of which are discussed. This type of a suspension makes it possible to control the zero position automatically without introducing restoring forces that would give rise to undesirable oscillations.

FRIDAY AFTERNOON AT 2:00

Room 19, Chemistry Building

(R. F. BACHER presiding)

Contributed Papers

G1. The Elastic Scattering of Protons by Oxygen.* R. A. LAUBENSTEIN,† M. J. W. LAUBENSTEIN, R. C. MOBLEY, AND L. J. KOESTER,‡ *University of Wisconsin.*—The yield of elastically scattered protons from oxygen has been measured using a magnetic analyzer which detected protons scattered through laboratory angles of 159° to 169°. The proton energy range from 0.6 to 4.5 Mev was covered in 4.4-kev steps using protons from the Wisconsin electrostatic generator. Targets of BaO on 1000A nickel foil and on diamonds were used. At 2.66-Mev proton energy a resonance was observed with a width of 20 kev and at 3.47 Mev a resonance was observed with a width less than 3 kev. Near 4.0 Mev a broad maximum in the scattering cross section was obtained and a broad resonance appears to give another maximum slightly over 4.5 Mev. The resonance at 2.66 Mev was obtained as a nearly symmetrical dip in the scattering cross section. An analysis of part of the data in terms of potential scattering theory has been made.

* Work supported by the AEC and the Wisconsin Alumni Research Foundation.
† Now at North American Aviation, Inc.
‡ AEC Predoctoral Fellow.

G2. Capture of Protons by Oxygen.* M. J. W. LAUBENSTEIN, R. A. LAUBENSTEIN,† L. J. KOESTER,‡ AND R. C. MOBLEY, *University of Wisconsin.*—The capture cross section of oxygen for protons has been measured for incident proton energies from 1.4 to 4.1 Mev by counting the positrons from the decay of the F^{17} built up under the bombardment of oxidized tantalum targets. A method for compensating for fluctuating beam current was used and aluminum absorbers were used to prevent the counting of positrons from F^{18}. The cross section increases almost linearly with proton energy up to a maximum at 4 Mev except for a sharp resonance at 3.47 Mev. The effect of the level at 2.66 Mev was not detectable within the experimental error. The half-life of F^{17} was measured as 66.3 ± 1 sec. An estimate of the beta-ray end point obtained from absorption measurements gave 1.75 ± 0.2 Mev. The correspondence of the levels in F^{17} and its mirror nucleus O^{17} will be shown.

* Supported by the AEC and the Wisconsin Alumni Research Foundation.
† Now at North American Aviation, Inc.
‡ AEC Predoctoral Fellow.

G3. Some Pair-Theoretic Applications of the Dispersion Relation. JOHN TOLL AND JOHN A. WHEELER, *Los Alamos Scientific Laboratory and Princeton University.*—Analyzing different formulations of conditions for validity of the dispersion formula relating absorption and refraction of light, especially the condition that no wave be scattered before arrival of the primary wave (Kronig) we conclude: it is reasonable to apply the dispersion formula for arbitrarily high fre-

quencies. (1) From the Breit-Wheeler formula for pair *production* by two photons, the dispersion relation yields for all frequencies the cross section for forward *scattering* of light by light, and agrees with high and low frequency limits of Achieser, and Euler and Kockel, respectively. (2) We calculated the linear *absorption* coefficients for light in vacuum polarized by a uniform and static electromagnetic field. The dispersion relation then yields for all frequencies the *refractive index* of a polarized vacuum. (3) From the field Lagrangian of Heisenberg and Euler, we compute the refractive index of low frequency light in vacuum polarized by sinusoidally varying or constant background field. Results agree with (1) and (2). Reversing the reasoning gives the fourth-order terms in the Lagrangian without employing difficult fourth-order subtraction-theoretic calculations used by Heisenberg and Euler.

G4. Bases for an Estimate of Coherent Gamma-Ray Scattering. JOHN A. WHEELER AND JOHN TOLL, *Los Alamos Scientific Laboratory and Princeton University.*—Employing the dispersion formula (preceding paper), one can estimate coherent gamma-ray scsttering. (a) The equivalent oscillator strength in each elementary frequency interval is found from known or estimated absorption at that frequency. (b) The amplitude of the elementary wave scattered in the forward direction is accurately given by the dispersion formula. (c) Elementary waves decrease at other angles according to a form factor which is suitably estimated: (i) for photoelectric and Compton processes from known atomic wave functions; (ii) for nucleonic processes from available information on relative strengths of dipole and quadrupole transitions; (iii) for mesonic absorption, assuming dipole transitions and adopting for individual nucleons two extreme pictures of a region of absorption of negligible extent and of extent of the mesonic wavelength, and combining contributions of the nucleons in accordance with a nuclear-radius-dependent form factor; (iv) for pair production, from Williams-Weizsäcker picture of space localization of pair creation processes. One thus finds approximate dependence of coherent scattering upon atomic number, gamma-ray energy, and scattering angle. One cannot exclude the possibility that new absorption processes enter at still higher frequencies which contribute to gamma-ray scattering even in the Mev region. Hence measurements of the coherent scattering would be most interesting.

G5. Cross Sections of Thermonuclear Reactions. W. A. FOWLER, *Kellogg Radiation Laboratory, California Institute of Technology.*—An analysis of the experimental data on the cross sections at low energies of the thermonuclear stellar reactions has been made. The results yield the empirical constant, a, in an expression for the cross section of the form $\sigma=(a/E_1)\exp(-0.989\ Z_0Z_1M_1^{\frac{1}{2}}E_1^{-\frac{1}{2}})$ where E_1 is the energy of the incident particle in Mev and M_1 is its mass in amu. In the direct proton-proton cycle it is believed that the cycle is most probably completed by the reaction $He^3(He^3, 2p)He^4$ and a value for a for this reaction is estimated using $\Gamma_p\sim 0.1$ Mev. This would suggest an abundance ratio of $He^3/He^4\sim 10^{-4}$ for conditions at the center of the sun. The values for a in Mev-barns are as follows: $C^{12}(p,\gamma)$, 2.0×10^{-3}; $C^{13}(p,\gamma)$, $\geq 10^{-2}$; $N^{14}(p,\gamma)$, 2.5×10^{-2}; $N^{15}(p,\alpha)$, 110; $N^{15}(p,\gamma)$, 10^{-2}; $H^1(p,\beta^+)$,[1] 2.6×10^{-25}; $D^2(p,\gamma)$, $3.1(1+40E_1)\times10^{-7}$; $He^3(He^3,2p)$, ~ 2. This work was assisted by the joint program of the ONR and AEC.

[1] E. E. Salpeter, private communication.

G6. Performance of a High Energy Linear Electron Accelerator.* R. F. POST AND N. S. SHIREN, *Stanford University.*—The operating characteristics of the Stanford "Mark II" accelerator will be described. This accelerator, the second linear accelerator to be constructed at Stanford, was designed to be a prototype of the sections of the Bev machine now under construction. The Mark II accelerator tube is 12 feet in length and is designed to deliver a 1-microsecond pulse of 50-Mev electrons at the design power input. Performance to date is in good agreement with theory.[1] Energy spectra have been observed with about the expected shape and with peak energies in close agreement with the calculated values. With the available power (limited by power supply overloading) electrons up to almost 35 Mev have been observed, corresponding to an acceleration of 4.5 Mev per foot at the input end of the accelerator. Changes in peak energy with variations in power, frequency, and wave-guide temperature distribution will be discussed. This accelerator is in use for experiments in electron physics. Some of the problems arising in the use of this machine will be mentioned.

* The work reported herein was performed under a contract between Stanford University and the ONR.

[1] Ginzton, Hansen, and Kennedy, Rev. Sci. Instr. **19**, 89 (1948).

G7. Theory of Errors in a Linear Electron Accelerator.* L. I. SCHIFF AND R. F. POST, *Stanford University.*—The effect of random constructional errors in the individual cavities of a linear electron accelerator is calculated and, where possible, the theory is compared with experiment. The particular case of traveling wave accelerators (such as those at Stanford) is considered in detail. Assuming the statistical independence of errors in the several unit cells of the accelerator wave guides it is shown that for single-feed operation, the expected minimized fractional energy loss is given by the expression

$$\frac{\delta W}{W}=\frac{1}{30}M\sigma^2,$$

where M is the number of unit cells and σ is the root-mean-square phase error increment per cell, measured in radians. The effects due to frequency variations and temperature gradients in the guide are calculated. It is shown that the traveling wave design exhibits marked insensitivity to errors and to such changes in operating conditions, in comparison with a separate resonator, standing wave type of acclerator.

* The work reported herein was performed under a contract between Stanford University and the ONR.

G8. Approximate Quantization of Nonlinear Bose Field. R. FINKELSTEIN, *University of California at Los Angeles* AND M. RUDERMAN, *California Institute of Technology.*—The addition of an invariant $-g\varphi^*\varphi\varphi^*\varphi$ to the usual Lagrangian for scalar bose fields yields a nonlinear differential equation. Viewed as a classical field equation, a discrete set of particle-like solutions can be found corresponding to positive, negative, or zero charge. This same state of affairs can be described quantum-mechanically in the configuration space formalism of Fock and Tomonaga. The state of the field is represented as a superposition of states with various numbers of plane wave bosons. Estimates can be made of the average number of bosons in the field and quantum fluctuations from this number. Finite quantum corrections to the classical mass spectrum can only be calculated by modifying the usual commutation rules.

G9. Nonlinear Spinor Fields. R. FINKELSTEIN AND R. LELEVIER, *University of California at Los Angeles* AND M. RUDERMAN, *California Institute of Technology.*—In view of the possibly fundamental role of spinor fields in the theory of matter (symmetric coupling between nucleons, muons, and leptons, and possibility of representing boson fields in terms of spinors) one may ask whether all the elementary particles may be described in terms of a single nonlinear spinor field. Lagrangian densities of the following type have been investigated: $L=\sigma I_0+I_1+Q(I_0,\ I_1,\ J)$, where $I_0=i\varphi^+\varphi$, $I_1=(i/2)(\varphi^+\gamma_u\partial_u\varphi-\partial_u\varphi^+\gamma_u\varphi)$, Q is a simple nonlinear function, and J signifies other invariants constructed from the

sponor field. $Q=0$ corresponds to the usual Dirac Lagrangian. Typical cases studied are $Q=\epsilon I_0^2$ and $Q=\epsilon \sum_1^4 (\varphi^+\gamma_u\varphi)^2$, the latter form corresponding to Rosenfeld-Møller meson theory. Classical solutions of the field equations, having simple angular and temporal dependence, and depending on only two radial functions, the usual large (F) and small (G) components, were obtained subject to the boundary conditions that the fields be regular and that all observable integrals be finite. These b.c. lead to a nonlinear eigenvalue problem, best described in the $F-G$ plane; in this plane a complete qualitative discussion of the nature of the solutions can be given. Numerical solutions were obtained with a differential analyzer. If the charge, spin, and mass are defined in terms of $\int s_4 d\mathbf{x}$, $\int M_{4x_0} d\mathbf{x}$, and $\int T_{44} d\mathbf{x}$, respectively, then the number of masses corresponding to the same charge turns out to be small in all cases investigated. In one case there are three masses, all having the same spin and charge, but these do not correspond to electron, muon, and nucleon. A noteworthy feature of results is that in certain cases the nonlinearity leads to solutions having positive mass *only*; in that case the formalism of hole theory would be unnecessary.

G10. A Device to Assist Injection into Betatrons. LEVERETT DAVIS, JR., *California Institute of Technology*.—An electron in a betatron or synchrotron oscillates about the steady-state orbit; i.e., the orbit that closes in one revolution. This orbit is rarely precisely a circle. In order that the electrons not be removed from the beam by striking the injector within the first few revolutions, it is necessary either that the oscillations be damped or that the steady-state orbit be shifted away from the injector during injection by some significant change in the situation. A variety of suitable changes have been proposed at various times. It is here proposed that a possible procedure would be a transient bending on the steady-state orbit in the neighborhood of the injector. Transient magnetic or electric fields, established before the start of injection and removed during injection, could sweep the steady-state orbit and the circulating electrons from a displaced path close to the injector at the start of injection to the normal position farther away at the end of injection. The amount of difficulty required to produce properly adjusted auxiliary fields has not been investigated carefully. However, this procedure should facilitate the use of doughnuts of minimum cross section except for a short enlargement near the injector.

G11. Scattering of Magnetic Poles by Atomic Nuclei. KENNETH FORD AND JOHN A. WHEELER, *Los Alamos Scientific Laboratory and Princeton University*.—The nucleus is assumed very heavy compared to the pole. The pole is treated relativistically by the Klein-Gordon equation. The interaction problem is comparable with that of Rutherford scattering in symmetry and elegance. These features drew our attention to the problem more than any belief in the existence of poles. The differential cross section times the square of the momentum is independent of the mass of the pole and of its velocity and varies at small angles much as the Rutherford cross section. At larger angles we find from a classical calculation certain characteristic singularities in the cross section at the "rainbow angles" 140.1°, 156.7°, 163.5°, . . ., independent of the integer $n=$(nuclear charge in units e)$\times$(pole strength in units $137e/2$). The solution of the quantum-mechanical problem has been given as a formal series by Banderet. We have evaluated the series for $n=1, 2, 3$, where we find no trace of the classical singularities, and at $n=20$, where the angular distribution shows well-defined peaks near the first few rainbow angles. Generalizing, we conclude that scattering by heavy nuclei at certain universal angles is one characteristic of that quite possibly mythological entity, the magnetic pole.

G12. Zero-Zero Transition. S. D. DRELL, *Stanford University*.*—In the decay of a nucleus from an excited level of zero spin to a lower lying state of zero spin with no parity change, an orbital electron will be ejected from its path about the nucleus or, if the one excited level of the nucleus is higher than 2 mc^2 above the other level, an electron-positron pair may be created as well. Selection rules strictly forbid single gamma-emission. It is a unique property of these zero-zero transitions that the perturbing fields which induce the internal conversion or pair formation vanish identically outside of the nuclear radius.[1] Hence it is of particular interest to consider the effect of finite nuclear radius on the calculated rates of such processes. Presented here is a study of this effect. The K- to L-shell conversion ratio is independent of nuclear matrix elements. It is found to agree, within 10 percent, with the ratio as calculated for electrons in a point Coulomb field. Experimental data are employed to yield an approximate and reasonable value of $\frac{1}{5}(1.4\times10^{-13})^2A^{\frac{1}{3}}$ cm^2 for the nuclear matrix elements for the zero-zero transitions in RaC′, O^{16}, and Ge^{72}.

* Work performed at Oak Ridge National Laboratories under the auspices of the AEC.

[1] R. H. Fowler, Proc. Roy. Soc. **A129**, 1 (1930). H. Yukawa and S. Sakata, Proc. Phys.-Math. Soc., Japan **17**, 397 (1935).

G13. Scattering and Absorption of Gamma-Rays. S. T. COHEN, *Rand Corporation*, AND M. S. PLESSET, *California Institute of Technology*.—A formulation is presented of the scattering and absorption of gamma-rays which is suitable for radiological and shielding problems. For distances from a source small compared with the mean free path, only the unscattered and singly scattered beam need be considered. In this case, the results for the number of gamma-rays and the energy transmitted, as well as for the ionization produced, may be presented in useful and compact form. These calculations are compared with some experimental observations made on the transmission through air of gamma-rays of energy 3 mc^2. The transmission of gamma-rays through large thicknesses of materials is also discussed, and results for this case are presented for some light materials and for lead. These latter results are expressed in terms of a B-factor which is the ratio of total transmitted energy to the energy transmitted in the unscattered beam.

G14. Processing and Exposure of Electron-Sensitive Emulsion to High Energy Electrons and Positrons. CHARLES E. VIOLET, F. C. GILBERT, AND WALTER H. BARKAS, *University of California, Berkeley*.—In order to use sensitive emulsions for the study of electron interactions, it is necessary to erase the old tracks which interfere with the analysis. We have adopted a method suggested by J. Spence* for this purpose. The plates are kept at a temperature of 95°F in saturated water vapor for 60 hours just prior to use. This treatment eradicates virtually all the old electron tracks. After exposure the plates are developed using a modification of a procedure devised by Occhialini. With this development high energy electron tracks have a grain density of 40 grains/100 microns in G-5 emulsion. Tracks to be used in measuring mean free paths in emulsion for various electron and positron processes were produced by exposing G-5 plates in a magnetic pair spectrometer situated in the x-ray beam of the synchrotron. Separated electrons and positrons of 200, 100, 70, 40, and 20 Mev were recorded. This work was performed under the auspices of the AEC.

* Kodak Research Laboratory, Eastman Kodak Company.

G15. High Energy Electron Processes in Nuclear Emulsion. F. C. GILBERT, CHARLES E. VIOLET, AND WALTER H. BARKAS, *University of California, Berkeley*.—The existence of electron sensitive emulsions and a technique for eradicating accumulated background has made possible the study of high energy

electron and positron processes taking place within the nuclear emulsion. Tracks of magnetically separated electrons and positrons of 200-Mev energy produced by the synchrotron have been studied. The length of track scanned is recorded, and each measurable event is analyzed. The following processes have been observed: 1. Pair production by electrons and positrons, 2. electron-electron scattering, 3. positron-electron scattering, 4. nuclear scattering of electrons and positrons. The absolute cross sections for these processes are being determined. The results will be reported and photographs of events shown. This work was performed under the auspices of the AEC.

FRIDAY AFTERNOON AT 2:00

Room 45, Chemistry Building

(V. O. KNUDSEN presiding)

Contributed Papers

H1. Silver-Bearing Phosphate Glasses as Dosimeters. R. S. ALGER AND R. A. LEVY, *U. S. Naval Radiological Defense Laboratory* (introduced by R. I. Condit).—The fluorescence of certain silver-bearing phosphate glasses, which can be activated by exposure to x-rays, has been suggested as a basis of x-ray detection.[1] The x-rays reduce the silver ions to form impurity centers which make the glasses sensitive to ultraviolet excitation. The fluorescent yield has been measured as a function of x-ray dose for glasses containing up to 16 percent silver.[2] A piece of glass the size of a dime containing 8 percent or more silver will detect doses ranging from 25 to 2500 *r* at an effective x-ray energy of 100 kev. The fluorescent yield continues to increase after the x-ray exposure is terminated until a value is reached which is stable under moderate room illumination; however, direct exposure to sunlight, heat, or intense light reduces the fluorescent yield over a period of hours. Below 200 kev the fluorescent yield depends strongly on the effective energy of the x-rays. The maximum yield occurs at about 50 kev effective where the height of the peak is 15 times the value at 1 Mev.

[1] Wayle, Schulman, Gunther, and Evans, J. Electrochem. Soc. **95**, No. 2, 70 (1949).
[2] The glasses were furnished by Dr. J. Schulman of the Naval Research Laboratory, Washington, D. C.

H2. The Response of Geiger-Mueller Survey Instruments to Beta-Rays. E. TOCHILIN, A. B. WILLOUGHBY, AND P. R. HOWLAND, *U. S. Naval Radiological Defense Laboratory.*—G-M survey instruments have been investigated for their ability to measure correctly beta-rep doses over a range of beta-ray energies. Widespread laboratory employment of these instruments to assess tolerance doses of beta-radiation prompted this investigation. Theoretical considerations are presented which show that the number of counts recorded by a G-M tube for a given dose in rep units is proportional to: $E_{Av}^{1} \exp(-5.1g/E_{Av}^{4/3})$ where g is the wall thickness of the tube in g/cm² and E_{Av} is the average beta-ray energy. For a counter having negligible wall thickness the value of the exponent approaches unity and the number of counts per rep becomes proportional to the one third power of the average beta-ray energy. G-M instruments employing a cylindrical counter with a wall thickness of 30 mg/cm² and instruments employing an end-window counter with window thickness approximating 0 mg/cm² were investigated experimentally using beta-ray isotopes with maximum energies from 0.5 to 3.0 Mev. Absolute dose rates from the isotopes were obtained by extrapolation chamber measurements. Theoretical and experimental curves are presented for the two types of G-M instruments. In general, the rep response of both types of instruments agrees with predicted values.

H3. Current Carriers in Metals Exhibiting Positive Effects. SHELDON BROWN AND S. J. BARNETT, *California Institute of Technology and University of California, Los Angeles.*—Earlier direct measurements of e/m for the carriers in metals at normal temperatures have been made only on Cu, Ag, and Al, which have negative Hall coefficients, as predicted on the simple theories of conduction by (negative) electrons. A method suggested by Maxwell, but modified and first used with success by one of us[1] on copper, has now been further modified and extended to molybdenum and zinc, which have *positive* Hall coefficients. The existence of positive *carriers*, however, which would account simply for such coefficients, is apparently ruled out by the results of these experiments: Current and momentum of carriers are found to be oppositely directed even in metals having positive Hall coefficients. For both molybdenum and zinc the sign of e/m was found to be negative and the magnitude approximately identical with that for free electrons in slow motion. In experiments closely related to our own, but on *lead* (which also has a positive Hall coefficient at ordinary temperatures) Kikoin and Goobar[2] have shown that this material when in the *supraconducting* state gives the same value of e/m.

[1] S. J. Barnett, Phil. Mag. **12**, 349 (1931).
[2] Kikoin and Goobar, J. Phys. U.S.S.R. **3**, 333 (1940).

H4. The Attenuation of Ultrasonic Waves in Electrolytic Solutions.* O. B. WILSON, JR., *University of California, Los Angeles.*—The absorption coefficient for sound waves in several bivalent metal sulfates has been measured by a reverberation technique[1] over the frequency range 50–500 kc. In all cases studied, the measured absorption is larger than that which could be attributed to an increase in the shear viscosity coefficient. The absorption in $MgSO_4$ solutions is largest and is representable as a relaxation-type absorption in which the relaxation frequency lies within the range of these measurements. Graphs depicting the dependence of the absorption and relaxation frequency in $MgSO_4$ solutions upon the salt concentration and the temperature will be presented. Following Liebermann,[2] a possible explanation for these results will be discussed briefly in terms of a chemical equilibrium in the ionic solution which is perturbed by the passage of the sound wave.

* Research supported by Contract with the ONR, Contract N6 onr 27507.
[1] R. W. Leonard, Tech. Report No. 1, Project NRO14-302, University of California, Los Angeles.
[2] L. N. Liebermann, Phys. Rev. **76**, 1520 (1949).

H5. Measurement of the Grazing Incidence Sound Field over an Absorbing Boundary. ROBERT B. LAWHEAD, *University of California, Los Angeles.*—Plane wave reflection theory has long been recognized as inadequate to explain grazing incidence propagation of electromagnetic or acoustic waves. The solution for the electromagnetic radiation from a vertically polarized dipole at the surface of a plane earth is now well known, and has received a great deal of attention

both theoretically and experimentally since the first work of Sommerfeld[1] in 1909. It was not until recently that the analysis used for the electromagnetic case was applied to the acoustic problem and a similar solution obtained.[2] This paper reports the results of measurements made in the frequency range 1–4 kc, using Fiberglas of three different densities as the acoustic boundary. With the sound source located at the boundary, the values of pressure amplitude and phase lag as a function of both receiver distance and height above the boundary show good agreement with theory.

[1] A. Sommerfeld, Ann. Physik **28**, 665 (1909).
[2] I. Rudnick, J. Acoust. Soc. Am. **19**, 348 (1947).

H6. The Absorption of Sound in Foggy Air at Low Audible Frequencies. YUNG TSIOH WEI, *University of California, Los Angeles* (introduced by L. P. Delsasso).—The anomalous sound absorption in water fog at low audible frequencies observed by Knudsen, Wilson, and Anderson has been further investigated by the method of standing waves. The theory on this effect given by Oswatitsch is critically examined and certain modifications proposed. Measurements were made in the frequency range of 25–250 cps for artificial fogs of several different concentrations and average droplet sizes. Artificial fogs produced by a water sprayer were introduced into the measuring tube and both droplet size and concentration measurements were made simultaneously with the acoustic measurements. The observed attenuation coefficients of the fog were computed from the ratios of the first pressure minimum to first maximum of the standing wave pattern with and without the fog. The maximum attenuation coefficients varied from 8.8 db/sec to 20.8 db/sec. The positions of maximum absorption were found to vary in the frequency range 35 to 50 cps. The calculated values based on both Oswatitsch's and the modified theory are compared with the experimental values. The experimentally obtained attenuation coefficients due to evaporation and condensation processes are found to be higher than those computed by both theories throughout the lower frequency range but in better agreement with the modified theory than with that of Oswatitsch.

H7. The Propagation of Sound in Carbon Dioxide Near the Critical Point. NEAL S. ANDERSON, *University of California, Los Angeles.*—The expression for the normal velocity of sound in a fluid becomes indeterminate at the critical point since the coefficient of elasticity tends to zero and the specific heat at constant pressure approaches infinity. An expression was obtained for the isentropic slope which does not become indeterminate at the critical point. A Pierce-type variable path acoustic interferometer was constructed to be placed completely inside a pressure tank with provisions for external control. The isothermal variation of velocity and absorption was measured as a function of pressure at 572 kc in carbon dioxide. The velocity variations agree with previously published results. The attenuation decreases steadily with increasing pressure and does show an abrupt rise as the critical point is reached which would be expected from critical fluctuation scattering. Using isotherm data the velocity at the critical point was calculated to be 198 meters per second. The experimental value obtained was significantly lower, being closer to the value of 148 meters per second which is obtained if van der Waals' equation of state is assumed.

H8. Measurements of Flame Speeds and Turbulence in a Mache-type Burner. F. H. WRIGHT, *Jet Propulsion Laboratory, California Institute of Technology.*—Combustion in a flowing system is known to be influenced by turbulence in the stream. How the turbulence exerts its influence is not known. Even the magnitude of the effect is uncertain because there are virtually no relevant experimental data. The measurements reported here do provide such data for one experimental configuration. The measurements were carried out in Mache-type burners (burner port dimension: 1×12, 2×12, 3×12, and 2×2 cm). Turbulence of variable intensity was produced by grids inserted upstream from the burner port. The turbulence in the stream with no combustion was measured with a hot wire anemometer. Flame speeds were measured both visually and photographically. The flame speeds were found to increase as the turbulence was increased. In fact, an approximately linear relationship was found to exist between the radio S_T/S_L and the dimensionless parameter v'/U. U is the mean speed of the stream, v' is the rms velocity of the cross component of the turbulence, S_T is the flame speed with turbulence v', S_L is the flame speed without turbulence. Within the accuracy of the measurements, so significant effect of side of burner or scale of turbulence was found.

H9. Growth of Critical Vapor Nuclei in Superheated Liquids. M. S. PLESSET AND S. A. ZWICK, *California Institute of Technology.**—A critical vapor nucleus is a vapor bubble for which the surface tension and the external pressure balance the vapor pressure at the given temperature so that any temperature rise of the liquid in which the vapor nucleus is situated causes the nucleus to grow. This growth is controlled by two factors: the inertia of the liquid, and the heat inflow requirements of evaporation to maintain the vapor pressure. The heat flow problem is of special interest since it represents a diffusion across a moving boundary. An approximate analytic solution for this diffusion problem has been found, and it is shown that the approximation is a good one. An analytic solution for the radius of the vapor bubble as a function of time has been derived which is valid for sufficiently large radius. This asymptotic solution covers the range of physical interest since the radius at which it becomes valid is near the lower limit of experimental observation.

* This study was supported by the ONR.

H10. A New Method for Measuring Transient Gas Densities. A. B. C. ANDERSON, *U. S. Naval Ordnance Test Station* (introduced by F. T. Rogers, Jr.).—A theoretical analysis of the dielectric properties of nonpolar gases (air, N_2, O_2, H_2, CO_2, Cl_4, CH_4, etc.) and an examination of available experimental data indicates, as pointed out elsewhere, that for such gases the dielectric constant is a linear function of the gas density alone. Over very wide ranges, the dielectric constant is independent of the particular values of temperature and pressure which determine the gas density. Thus, the capacitance of a capacitor with a gaseous dielectric is a linear measure of the density of the gas. The capacitance is independent of the gas pressure and temperature except as these are related to density by the gas law. Several capacitor pick-up arrangements are discussed for use as density pickups, and experimental data are presented for one of these, showing this type of instrument to be feasible. On the other hand, theoretical analysis of the dielectric properties of polar gases (H_2O, NH_3, HCl, H_2S, SO_2, etc.) shows that their dielectric constant depends on both density and temperature at ordinary capacitor excitation frequencies. It appears that the dielectric constant for all gases should be a linear function of the density alone.

H11. Factors Affecting Burning Rates of Solids. G. B. SHOOK, *U. S. Naval Ordnance Test Station.*—A differential equation for the burning of a solid is deduced from the thermal processes occurring within the solid, a general knowledge of the chemical processes, and the geometry. It is, for one-dimensional burning, $U_t = k^2 U_{xx} + A + B$, where $A = (\alpha I_0/c\rho) \times \exp(-\alpha x)$ and $B = (Hs/c) \exp(-E/RU)$ are heat sources within the solid due respectively to radiation absorption and the exothermic chemical reaction. Solutions of the above equation for $B = 0$ are obtained in closed form for boundary conditions pertinent to the ignition (i.e., incipient burning) and the burning periods. For the case $B \neq 0$, numerical methods

must be used. The effect of pressure, temperature, chemical reaction, and diffusion are discussed with respect to the parameters appearing in the mathematical model. In particular the absorption coefficient α, the radiant flux I_0 and the temperature of the burning surface U_1 are related to the gas density, temperature and geometry of the solid's environment, and it is shown that in some cases these factors may affect the predicted burning rate significantly.

H12. A Type of Fracture Produced in Steel by Explosive Attack. JOHN S. RINEHART, *U. S. Naval Ordnance Test Station, Inyokern.*—The phenomena of fracture are complicated and obscure. For this reason, Bridgman, among others, has encouraged workers in the field to acquire the broadest possible knowledge of the phenomena, particularly under extreme physical conditions. His studies, for example, on the effects of hydrostatic pressure on fracturing are well known. An equally fertile field for studies of fracture is that in which fracturing results from the application of the extremely high transient pressures that are produced by explosive charges. Among the more unexpected fractures, which occur in such cases, are those that can be attributed to the sudden release of the applied pressure. Several cases of this type of fracture have been observed in steel and are described. A quantitative treatment of the fractures in terms of known stress or strain distributions is not yet possible. Certain qualitative aspects of the stress distributions that probably exist during and immediately following application of the pressure are discussed and related to observe fracturing. Phenomenologically, the fractures seem to result from highly inhomogeneous stresses set up during application of the pressure, a volumetric expansion on load release, or a combination of both.

H13. Deceleration and Ionizing Efficiency of Meteors. D. W. R. MCKINLEY, *National Research Council, Ottawa,* (by title).—An improved technique for recording radar echoes from meteors has made it possible to determine the meteor deceleration in a few special cases. Three illustrative examples are described, with measured mean decelerations -0.48, -1.1, and -1.5 km sec^{-2}. Velocity data from a continuous-wave system were available for comparison with the radar observations. Using the present standard density values for the atmosphere at heights between 70 and 110 km, and adopting Lovell's scattering formula, it is computed that the ionizing efficiency, or the fraction of kinetic energy of the meteor converted to ionization, is 10^{-6} for a 60 km/sec meteor and 10^{-8} for a 20 km/sec meteor. With lower values of the air density the efficiency figures are increased, and the gap is narrowed between the rates of electron production deduced from loss of mass considerations and the rates calculated from the radar information. New data on the ionizing properties of 1000-ev atoms, and more radar observations are required before definite conclusions can be drawn regarding the upper air density and temperature.

H14. Optimum Source Size for the Mach-Zehnder Interferometer. F. D. BENNETT, *Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland,* (by title).—A vector analytic treatment is given of the formation of undisturbed fringes by an ideal Mach-Zehnder interferometer with an extended source. The path difference of two interfering rays at an arbitrary point in the field is found to depend in a simple way upon the source point from which the rays originate, the field point examined, and a dyadic which is a function of the unit normals to the last mirror and divider plate of the interferometer. The fringe clarity condition that all pairs of interfering rays reaching the field point have path differences within a specified range is developed in the form of an inequality. Analysis of this fundamental inequality shows that all admissible area sources must be areas enclosed between two conics in the source plane. For fringes normal to the plane of centers of the interferometer elements, the optimum source is a circle with radius inversely proportional to the square root of the number of clear fringes desired. This result holds for all interferometers of parallelogram planform. For fringes parallel to the plane of centers, each interferometer orientation presents a special case. The optimum source area is obtained for two of these, *viz.*, the 45° and 30° interferometers.

SATURDAY MORNING AT 9:00

Room 147, Business Administration and Economics

(C. C. LAURITSEN presiding)

Invited Papers

I1. Ozone in the Earth's Atmosphere. VICTOR H. REGENER, *University of New Mexico.* (30 min.)

I2. Some Observations Bearing on the Physical Basis for Cloud Seeding. E. J. WORKMAN, *New Mexico School of Mines.* (45 min.)

I3. Nuclear Models and Nuclear Fission. JOHN A. WHEELER, *Los Alamos Scientific Laboratory and Princeton University.* (45 min.)

SATURDAY AFTERNOON AT 2:00

Room 19, Chemistry Building

(E. H. PLESSET presiding)

Contributed Papers

J1. Radiations from Chlorine 34 (33 Min.). LAWRENCE RUBY AND J. REGINALD RICHARDSON, *University of California, Los Angeles.*—The spectrum of Cl^{34} has been studied in a large magnetic lens beta-ray spectrometer calibrated with the 661.4-kev internally converted gamma-ray of Ba^{137}. Zah-Wei Ho,[1] using a cloud chamber, obtained a gamma-ray of 3.4 Mev

and two groups of positrons with end points at 5.1 and 2.4 Mev. The activity was produced in the UCLA cyclotron by $S^{34}(p, n)Cl^{34}$ and by $Cl^{35}(p, pn)Cl^{34}$. The shape of the positron distribution and the fact that the Kurie plot could not be resolved into two components indicated the existence of three groups of beta-particles. Internal conversion electrons corresponding to a gamma-ray of 145±3 kev have been found. The decay of this line has been followed in the spectrometer for three half-lives to verify its origin in Cl^{34}. In addition, the L photo-electron spectrum has been observed. From Compton electrons produced in a Cu converter, two further gamma-rays have been identified. A tentative decay scheme which associates one gamma-ray with each group of beta-particles is summarized below. The maximum beta-energies have been determined from a Kurie plot.

Maximum beta-energy in Mev	Gamma-energy in Mev	Total
4.45±0.11	0.145±0.003	4.60±0.11
2.58±0.26	2.13 ±0.12	4.71±0.38
1.3 ±0.2	3.30 ±0.14	4.6 ±0.3

This research was supported in part by the joint program of the ONR and AEC.

[1] Zah-Wei Ho, Phys. Rev. **70**, 782 (1946).

J2. The Absolute Energy Loss of 18-Mev Protons in Various Materials. DONALD C. SACHS AND J. REGINALD RICHARDSON, *University of California, Los Angeles.*—It has been possible by use of a thorium scatterer and magnetic analysis in the magnetic field of the UCLA cyclotron to produce a small beam of 18-Mev protons monoenergetic to 0.15 percent. This is accomplished by 180° focusing and momentum selection. At the 180° point, the beam may be made to pass through a thin metallic foil, and then it is focused through an additional 180° to a movable slit above but near the original thorium scatterer. The displacement of the 360° focus caused by the presence of the metallic foil is a measure of the absolute energy loss in the foil. The experimental results show that the absolute energy loss in 0.006 in. of aluminum, for example, is determined to better than ±1 percent. This allows the determination of the "mean" ionization energy I to ±5 percent. This research was supported in part by the joint program of the ONR and AEC.

J3. Maximum β^+ Energy From Na^{21}. GLEN E. SCHRANK AND J. REGINALD RICHARDSON, *University of California, Los Angeles.*—A 180° β-ray spectrometer was used to measure the maximum energy of the 23-sec positron activity in Na^{21}, a member of the mirror nucleii series. The sample was prepared from the reaction $Mg^{24}(p, x)Na^{21}$ by bombarding a foil of pure Mg with 18.5-Mev protons. At this proton energy, the (p, n) reaction produces two activities, Al^{25} and Al^{26}, but since these both have half-lives of about 7 sec, a waiting period of 60 sec was sufficient to allow these activities to disappear. After this interval only the 23-sec activity could be detected. The intensity was sufficient to allow the determination of decay curves for two values of momentum for each sample. In this way a series of bombardments was made and combined in order to give an extrapolated Kurie plot upper limit of E max-2.53 ± 0.02 Mev. This is to be compared with the value 2.56 Mev calculated from the difference in the Coulomb repulsion terms of the mirror nuclei, using $R=1.42\times10^{-13}A^{1/3}$ cm.[1] This research was supported in part by the joint program of the ONR and AEC.

[1] Rosenfeld, *Nuclear Forces*, p. 383.

J4. An Experimental Determination of the Range of 18-Mev Protons in Aluminum. E. L. HUBBARD AND K. R. MACKENZIE, *University of California, Los Angeles.*—The circulating proton beam in the 41-in. FM cyclotron was scattered upward by a 14-mil strip of thorium placed inside the dee. The energy was defined by the Th strip, a 0.25-in. slit at 139°, and a 20-mil slit at 170°. The magnetic field along the path was plotted with a nuclear magnetic resonance probe and the energy determined by graphical methods. Part of the 10^{-11} amp beam current that passed through the slits was collected by a 452.94 mg/cm² Al plate and part by a cup behind it. The current was measured with an electrometer tube. Fine adjustments of the effective thickness of the Al plate were made by placing thin Al foils in front of it. The mean range is the thickness for which the currents collected by the plate and the cup are equal. A preliminary result gives a range of 476.5±5.0 mg/cm² for an energy of 18.00±0.10 Mev. It is expected that the limits of error will be reduced by a factor of 5. This research was supported in part by the joint program of the ONR and AEC.

J5. Isomers in Cr and Mn. DAVID O. CALDWELL* AND HUGH F. STODDART, *Los Alamos Scientific Laboratory.*—Two activities ascribable to isomeric states in 29-neutron nuclei, have been found, one of which might serve as a test among nuclear shell structure theories. The activity in Cr variously described [1–3] as having a half-life of 1.3 to 2.3 hr has recently been shown[4, 5] not to be due to Cr^{55}. This disputed activity has been produced by activating normal and enriched (in Cr^{52}) Cr, both by 10-Mev deuterons and by thermal neutrons. The activity being stronger in the enriched targets indicated that the negatrons being counted were conversion electrons from an excited state in Cr^{53}. The second activity is a 2.1-min negatron, ascribed to an excited state in Mn^{54}, because of the ratio of activities in normal and enriched (in Fe^{54}) Fe after bombardments by 14-Mev neutrons and 10-Mev deuterons.

* Now at UCLA.
[1] Dickson, McDaniel, and Konopinski, Phys. Rev. **57**, 351 (1940).
[2] Amaki, Iimori, and Sugimoto, Phys. Rev. **57**, 751 (1940).
[3] Seren, Friedlander, and Turkel, Phys. Rev. **72**, 888 (1947).
[4] M. E. Nelson and M. L. Pool, Phys. Rev. **77**, 682 (1950).
[5] D. R. Miller, Phys. Rev. **78**, 808 (1950).

J6. Deuteron-Proton Scattering at 190 Mev. A. L. BLOOM AND M. O. STERN, *University of California, Berkeley.*—The differential cross section for elastic scattering of 190-Mev deuterons on protons has been measured at several angles, using the external deuteron beam of the 184-in. Berkeley cyclotron. A coincidence counting method was used, in which two stilbene scintillation counters were placed so as to count the scattered protons and deuterons simultaneously. The deuteron counter was large enough to count the deuteron corresponding to any proton that entered the proton counter. The target was polyethylene, alternating with a carbon target to measure background. The results show maxima in the backward and forward directions, corresponding to exchange effects and the pick-up process, in agreement with the theoretical predictions of Chew.[1] This work is sponsored by the AEC.

[1] G. F. Chew, Phys. Rev. **74**, 809 (1948).

J7. Cross-Sections for $S^{32}(\gamma, n^d p)P^{30}$ and $Rb^{87}(\gamma, \alpha)Br^{83}$ Reactions. E. L. HARRINGTON, L. KATZ, R. N. H. HASLAM, AND H. E. JOHNS, *University of Saskatchewan.*—Cross-section curves for the gamma-deuteron reaction in S^{32} and the gamma-alpha-reaction in Rb^{87} have been determined by analysis[1] of the activation curves of the resulting nuclides. The observed threshold for the (γ, d) reaction which leads to a pure 2.55-min P^{30} activity is 19.15±0.20 Mev, in good agreement with the value calculated from known reaction energies.[2] The cross-section curve may be interpreted as a superposition of curves for a (γ, d) and a (γ, np) reaction. The half-width of the combined cross section is about 3 Mev, with peaks at 24 and 26 Mev. The integrated cross section is 4.1×10^{-3} Mev-barn. In the case of $Rb^{87}(\gamma, \alpha)Br^{83}$ a chemical separation is necessary to isolate the weak 140-min bromine activity. Measurable activities were first observed at 16 Mev. The cross-section

curve has a maximum at 22.5 Mev, half-width of 6.6 Mev, and the integrated cross section is 4×10^{-4} Mev-barn. Arguments in support of the reaction $Rb^{87}(\gamma, \alpha)$ rather than $Rb^{85}(\gamma, 2p)$ are advanced.

[1] Katz, Johns, Douglas, and Haslam, Phys. Rev. **80**, 131 (1950).
[2] A. S. Penfold, Phys. Rev. **80**, 216 (1950).

J8. Proton-Proton Scattering in the Energy Range 120 to 345 Mev. O. CHAMBERLAIN, E. SEGRÈ, AND C. WIEGAND, *University of California, Berkeley.*—Previously reported[1] measurements on the differential scattering cross section in proton-proton collisions have been refined with the use of stilbene scintillation counters and coincidence circuits with short (2×10^{-8} sec) resolving time. Some measurements have been made at energies lower than 345 Mev by placing lithium absorbers in the proton beam of the 184-in. Berkeley cyclotron. The most remarkable feature of the results is that in all cases the differential scattering cross section in the center-of-mass system is between 3.6×10^{-27} and 4×10^{-27} cm^2 sterad^{-1}. The energies studied and the range of angles included are as follows: 345 Mev (36° to 90°); 249 Mev (48° to 90°); 164 Mev (60° to 90°); 119 Mev (63° to 90°). In all cases the energies are those of the laboratory coordinate system, while the angles (and differential cross section) are those of the center-of-mass system.

[1] O. Chamberlain and C. Wiegand, Phys. Rev. **79**, 81 (1950).

J9. Elastic Scattering Survey Experiment. J. W. BURKIG AND BYRON T. WRIGHT, *University of California, Los Angeles.*—With equipment similar to that of Fulbright,[1] the elastic scattering cross section for 18.4-Mev protons at 79° of eleven elements was measured relative to W. The resulting values for Al, Fe, Ni, Cu, Pd, Ag, Sn, Ta, W, Pt, Au, and Pb were 0.53, 0.15, 0.17, 0.30, 0.53, 0.49, 0.38, 1.0, 0.92, 1.2, 1.3, 1.5 respectively. The probable error in these ratios varies from six percent to nine percent. For Al, Ni, Pd, and W relative angular distributions with points every 15° from 26° to 106° were obtained. For W the distribution decreases monotonically and a plot of $\log\sigma$ *versus* $\log\theta$ approximates a straight line whose slope is $b=-4.7$ as compared to a slope $b=-3.5$ for Rutherford scattering, using the expression $\log\sigma=a+b\log\theta$. Thus the observed angular dependence decreases faster than the Rutherford dependence. Pd has local variations as large as ±50 percent around Rutherford dependence. For $\theta>50°$ Ni and Al distributions decrease slower than the Rutherford curve and have variations up to ±50 percent about their average angular dependence. This research was supported in part by the joint program of the ONR and AEC.

[1] H. W. Fulbright and R. R. Bush, Phys. Rev. **74**, 1323 (1948).

J10. Alpha-Spectrum of $Li^8(\beta)2\alpha$ and $B^{11}(p, \alpha)2\alpha$ Reactions. C. W. LI AND WARD WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—There is evidence for the formation of a broad state in Be^8 of about 3-Mev excitation in at least 6 different nuclear reactions. The poor agreement between the excitation energy and width of this level observed in different reactions suggests the possibility of some structure. We have measured the energy spectrum of the alpha-particles from the two reactions (1) $Li^8(\beta)2\alpha$ and (2) $B^{11}(p, \alpha)2\alpha$ with a high resolution magnetic spectrograph and find no evidence of any structure in either reaction. The Li^8 was produced by deuteron bombardment of thin Li targets on thin Be foils, total thickness 0.7 mm air equivalent. After correcting the observed spectrum for the energy loss in the target, the peak in the alpha-spectrum is at $E_\alpha=1.52\pm0.02$ Mev and the width at half-maximum is 0.8 Mev. For reaction (2) thin targets of B_2O_3 on Cu were used. At a proton bombarding energy of 1.00 Mev and an angle of observation of 89.3 degrees, the peak in the alpha-spectrum is at $E_\alpha=4.37\pm0.02$ Mev and the width at half-maximum is 0.75 Mev. The experimental data must also be corrected for the motion of the center of mass and barrier penetration; however a preliminary analysis would indicate that possibly two different levels in Be^8 are involved in the two reactions. In reaction (2) a narrow alpha-line was observed corresponding to the formation of Be^8 in its ground state. The intensity of this weak group is 1/35 the intensity of the group corresponding to the formation of Be^8 in the 3-Mev excited state. This work was assisted by the joint program of the ONR and AEC.

J11. Interation of *S*-Wave Neutrons and Protons with C^{13}. R. G. THOMAS,* *Kellogg Radiation Laboratory, California Institute of Technology.*—In determining the reduced width of the *s*-wave $C^{12}(p, \gamma)N^{13}$ resonance at 0.456 Mev it is necessary to take into account the variation of the level shift with respect to energy. When this is done a value $\gamma^2\approx\hbar^2/Ma$ is obtained. This value is about equal to the reduced width expected for a simple one-body type of interaction. The reduced width of the low energy neutron *s*-wave scattering by C^{13} is also equally large. This width is determined by fitting a one-level dispersion curve, including potential scattering, to the neutron scattering data up to 2 Mev. In view of the large reduced widths of these interactions it is appropriate to analyze the data by means of the effective range theory. By taking the 3.10-Mev level in C^{13} as the bound state associated with the low energy neutron scattering, a scattering length of $6.1\cdot10^{-13}$ cm and an effective range of $3.0\cdot10^{-13}$ cm are obtained; with these parameters a good fit to the scattering data is obtained. The range and scattering length for the proton interaction, as determined from the gamma-ray and elastic scattering[1] experiments, are compared with the neutron interaction parameters. There is agreement within the uncertainties. The main difficulty in making a quantitative comparison is the lack of accurate knowledge of the Coulomb interaction for the proton within the nucleus.

* AEC Pre-doctoral Fellow.
[1] Goldhaber, Williamson, Jackson, and Laubenstein (to be published).

J12. *Q*-Values of the $Li^7(p, \alpha)\alpha$ and $Be^9(d, \alpha)Li^7$ Reactions. WARD WHALING AND C. W. LI, *Kellogg Radiation Laboratory, California Institute of Technology.*—The energy of the α-particles from the (1) $Li^7(p, \alpha)\alpha$ and (2) $Be^9(d, \alpha)Li^7$ reactions has been measured with a double-focusing 180° magnetic spectrograph. Both thick and thin metallic targets were used. Results have been corrected for the energy loss of incident and emitted particles in surface layers of C and O that appear on the target during bombardment. The spectrograph was calibrated against natural α-particles of energy close to the energy of the emitted particles, ThC′ for reaction (1), Po for reaction (2). Using exact masses and making appropriate relativistic corrections, $Q_1=17.338\pm0.011$ Mev, $Q_2=7.151\pm0.010$ Mev, where the probable error is calculated from various experimental uncertainties, principally in the angle of observation $89.3\pm0.2°$. Combined with the *Q*-values for the $Be^9(d, p)Be^8$ and $Be^8(\alpha)\alpha$ reactions, which have recently been measured with a magnetic spectrograph,[1] these *Q*-values give the α-particle mass in terms of the deuteron mass. Using 2.014723 ± 0.000004 for the mass of deuterium, we find for the mass of He^4 4.003840 ± 0.000018. This value, 0.060 mmu lower than the previously accepted value, is in excellent agreement with Ewald's[2] recent mass spectroscopic determination. This work was assisted by the joint program of the ONR and AEC.

[1] Tollestrup, Fowler, and Lauritsen, Phys. Rev. **78**, 372 (1950).
[2] H. Ewald, Z. Naturforschung **5A**, No. 1, 5 (1950).

J13. Excitation of the Reaction $C^{13}(p, \gamma)N^{14}$.* J. D. SEAGRAVE, R. B. DAY, AND J. E. PERRY, JR., *California Institute of Technology.*—An electrostatic accelerator has been used to obtain excitation functions between 400 and 2700 kev for the reaction $C^{13}(p, \gamma)N^{14}$. A thick target was made of C^{13}

enriched lampblack, and 1 to 20 kev thin targets were prepared by "cracking" enriched methyl iodide vapor on tantalum strips. Four previously unreported resonances have been located at $E_p = 1.16$, 1.3, 1.76, and 2.1 Mev. The resonance at 1.76 Mev exhibits a thick target yield 2.4 times that due to the well-known resonance at 0.554 Mev. Preliminary estimates are $\Gamma \leq 2$ kev and $\sigma \geq 3.5 \times 10^{-26}$ cm² at 1.76 Mev. The resonance centered at 1.3 Mev has a width of 600 kev and a thick target yield 1.6 times that due to the 0.554-Mev resonance. Coincidence counter measurements of the range of secondary electrons have been made at each resonance, and indicate that the transition to the ground state does not predominate at 1.16 and 2.1 Mev, as it does at 0.55 and 1.76 Mev. Assignment of these resonances to $C^{13}(p, \gamma)N^{14}$ has been confirmed by comparison with the yield of a thin target of normal carbon (1.1 percent C^{13}). This work was assisted by the joint program of the ONR and AEC.

J14. Angular Distributions of the γ-Rays from C($p\gamma$). R. B. DAY AND J. E. PERRY, JR., *Kellogg Radiation Laboratory, California Institute of Technology.*—The angular distributions of the γ-rays from $C^{13}(p\gamma)$ at the 1694-kev resonance ($\Gamma = 70$ kev) and from $C^{13}(p\gamma)$ at the 1754-kev resonance ($\Gamma \leq 2$ kev) have been investigated. The detecting apparatus consisted of G-M counters in coincidence mounted on a frame that could be rotated about an axis through the target. The angular distributions have the form $1 + a\cos^2\theta$, where a is as follows:

	$C^{13}(p\gamma)$ (60-kev target)			$C^{13}(p\gamma)$ (100-kev target)
E_p	1670 kev	1724 kev	1749 kev	1770 kev
a	-0.394 ± 0.056	-0.474 ± 0.019	-0.516 ± 0.018	-0.399 ± 0.013

No convincing evidence has been found for the existence of terms in $\cos\theta$ or powers of $\cos\theta$ greater than 2. The first three values were obtained with 0.030 in. of aluminum absorber between the counters. The last was with 0.250 in. of aluminum absorber so that the measured distribution is essentially that of the 9.2-Mev transition to the ground state. Correction for the resolution of the detector will increase the magnitude of the observed coefficients by about 10–15 percent. The exact correction to be applied is being investigated.

SATURDAY AFTERNOON AT 2:00

Room 45, Chemistry Building

(J. KAPLAN presiding)

Contributed Papers

K1. X-Ray Absorption Structure in the *K*-Edges of Gaseous Cl_2 and HCl. S. T. STEPHENSON, R. KROGSTAD, AND W. NELSON, *The State College of Washington.**—Previous measurements in this and other laboratories indicate lack of agreement between theory and experiment for the fine structure to be found on the short wavelength side of the K absorption edges of various molecular gases. Since the phase shifts for chlorine have been computed in detail, and since Cl_2 is a simple diatomic molecule it would appear that the theory of the structure to be expected for Cl_2 should be very good and should offer the best chance for agreement with experiment. A detailed study of the Cl_2 edge is being made using a vacuum x-ray spectrometer first as a single crystal instrument and later as a double crystal instrument. The single crystal results will be described. There are significant discrepancies between the theoretical predictions and the structure observed both with respect to position and intensity. Measurements on HCl will also be described.

* Supported in part by the ONR.

K2. Intrinsic Curvature of Anastigmatic Fields. W. WALLIN, *U. S. Naval Ordnance Test Station* (introduced by F. T. Rogers, Jr.).—An anastigmatic lens system has a natural, or intrinsic, amount of field curvature associated with its focal length. It is shown that in the absence of internal foci, radical departures from the intrinsic curvature are not feasible. The development deals with a lens system comprising an indefinite number of elements.

K3. Ray Tracing Using the IBM Card Programmed Electronic Calculator. WILLIAM A. ALLEN, *U. S. Naval Ordnance Test Station.*—The IBM Card Programmed Electronic Calculator has been applied to the problem of lens design. Optical design is an inverse process consisting of a provisional choice of optical parameters, an exhaustive mathematical study of such a tentative prescription, and subsequent refinement of the lens system. The standard ray tracing equations can be adapted easily for machine use. The mathematical treatment is algebraic rather than trigonometric. Examples of meridional and skew ray tracing are given. A satisfactory lens has been calculated and tested entirely by machine methods. For at least one complicated optical system including decentered elements, refracting and reflecting prisms, and a multiplicity of interfaces, the standard equations required generalization. A further generalization has been the coding of the machine to trace a skew ray through an aspheric surface of revolution. The machine is expected to be of value in the refining of optical systems, in the determination of optical shop tolerances, and in the investigation of existing prescriptions.

K4. First-Order Focusing of the Spherical Electrostatic Analyzer for Particles at Relativistic Speeds. F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station.*—Earlier calculations[1] of the focusing properties of the electrostatic analyzer for particles of relativistic speeds have been extended to the case of the $1/r$-potential focusing field. These reveal a marked "chromatic" dependence of focusing power upon $\beta = v/c$, known previously[2]; but, as in reference 1, there is no indication of anomaly or divergence as $\beta \to 1$. The equations describing focusing take on the usual standard forms and allow estimates readily to be made concerning regions of least confusion; effects of geometrical aperture and of the band width in energy for transmitted particles can likewise be estimated.

[1] C. W. Horton and F. T. Rogers, Jr., Rev. Sci. Instr. **14**, 216 (1943).
[2] E. M. Purcell, Phys. Rev. **54**, 818 (1938).

K5. Equilibrium in Rotating White Dwarf Stars. B. A. JACOBSOHN, *University of Washington.*—After having used up its hydrogen, a normal star contracts to a white dwarf with conservation of angular momentum. At a small enough radius, the centrifugal force becomes comparable to the gravitational force. There thus exists a mechanism through which a star which exceeds Chandrasekhar's critical mass will not collapse to a point. The equation of equilibrium for rotating degenerate

matter is solved for the case of large rotation by the use of a variational principle, employing simple trial functions for the density. In this way, approximate curves for the effective radius as a function of mass and angular momentum are plotted. The radius of Sirius B, which is two times larger than that predicted by Chandrasekhar's theory,[1] is examined from the point of view of these considerations.

[1] R. E. Marshak, Astrophys. J. **92**, 321 (1940).

K6. Precision Measurement of the Hall and Magneto-Resistivity Coefficients with some Results for Graphite.* W. P. EATHERLY AND J. J. DONOGHUE, *Atomic Energy Research Department, North American Aviation, Inc.*—A circuit capable of measuring alternating current potentials up to 1000 microvolts with a precision of 0.01 microvolt has been devised and applied to the measurement of the Hall and magneto-resistivity coefficients. The circuit is essentially an alternating current potentiometer whose out-of-balance signal is supplied to a peaked amplifier tuned by a parallel-T feedback network. The null of the amplifier output indicates the potentiometer balance. The circuit arrangement is particularly advantageous for the evaluation of the galvano-magnetic coefficients, since the circuit then becomes a voltage divider which is insensitive to current fluctuations. As an example, a set of data on the graphitization of gas-baked carbon is given. For this material marked changes in the electrical resistivity, the Hall effect, and the magneto-resistivity occur for graphitizing temperatures in the range 1700 to 2500°C. These are correlated with crystallite growth and the evaporation of impurities, and maybe qualitatively explained on the basis of the band structure and scattering of the conduction electrons. The precision computed from this set of data is representative and amounts to 0.4 percent and 0.1 percent, respectively, of the terminal values for the Hall and magneto-resistivity coefficients.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

K7. A New Apparatus for Determining the Magnetic Susceptibility of Very Small Samples.* J. J. DONOGHUE, *Atomic Energy Research Department, North American Aviation, Inc.*—An apparatus has been constructed for the precise determination of the magnetic susceptibility of very small samples by the Faraday, or non-uniform field method. Pole faces of a new design have eliminated the effect of errors in positioning the sample, by producing a uniform vertical force field within the gap. While the sample may be of arbitrary geometry, provision is made for accommodating an elongated shape. This is done by means of pole faces whose surfaces are parallel transcendental cylinders. The required equipotential surfaces were found by straightforward application of two-dimensional potential theory. Exploration of the gap with a small specimen indicated that a uniform force field existed over a large fraction of the volume within the gap. Measurable deviations from uniformity appeared only when edge or saturation effects became evident. An electrodynamic balance similar to that described by McGuire and Lane[1] has been used to measure the force on the sample. The detectable change in $m\chi$ of 1×10^{-10} g-cgs units is at present limited by tremors in the balance transmitted from the foundation.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.
[1] T. R. McGuire and C. T. Lane, Rev. Sci. Instr. **20**, 489 (1949).

K8. Graphical Location of Approximate Roots of a Polynomical and More Accurate Values of a Particular Root with a Mechanical Harmonic Synthesizer. S. LEROY BROWN, *University of Texas.*—It has been shown that the real roots of a polynomial of degree as high as fifteen may be determined with the aid of a mechanical harmonic synthesizer.[1] By a change of variable to a trigonometric function, and after expansion of the powers of the trigonometric function into functions of multiple frequencies, the roots of the polynomial are determined from a graph that is traced by the mechanical harmonic synthesizer. If the variable in the polynomical is changed to $\cos\theta$, approximate values of all roots having values between -1 and $+1$ are determined from a graph as θ is varied (by the synthesizer) from zero to 180°; and if the variable is changed to $1/\cos\theta$, approximate values of all roots are determined except those between -1 and $+1$. Once the approximate value of a root is determined, a more accurate value may be found from a graph (traced by the synthesizer) after the variable has been changed to a trigonometric function that changes only slightly from the approximate value.

[1] S. Leroy Brown and Lisle L. Wheeler, J. Frank. Inst. **231** (March, 1941).

K9. A High Speed Camera with Electronic Controls. R. B. BOWERSOX, *Jet Propulsion Laboratory, California Institute of Technology.*—A new high speed motion picture camera has been constructed to take pictures at a maximum rate of 50,000 frames/sec. It features independent control of the framing rate and the duration of each exposure as well as electronic Kerr cell shutters which permit easy synchronization with transient phenomena. The camera takes 620 frames on a 4-ft strip of 70-mm film with exposures of 1 microsecond or longer. The film strip is mounted on the inside of a drum 15 in. in diameter which may be rotated by an electric motor at speeds up to 5000 rpm. The frames, each 0.3-in. square, are arranged in four parallel rows in order to make room for more pictures in one revolution of the camera drum. Four small camera lenses with a Kerr cell in front of each are mounted in a vertical line inside the drum near the film. The lens aperture of f/2.5 combines with the transmission of the Kerr cell gives an effective aperture of f/5.0. One or more #22 flash bulbs have been found to give sufficient illumination for most subjects.

K10. Diffraction of a Plane Electromagnetic Wave by a Circular Aperture. M. J. EHRLICH, *Hughes Aircraft Company.*—Measurements have been made, both in phase and amplitude, of the electric and magnetic field components of the near zone diffraction region. The components were measured for a series of apertures ranging from one-half to fifteen wavelengths in diameter. The scattered field components were also measured for the complementary obstacles. The range of obstacle diameters was that of the circular apertures. Normal components of magnetic field are present in the near zone of the aperture and normal electric components in the near zone region of the complementary obstacle. The tangential electric field displays considerable variation, both in phase and amplitude, across the plane of the aperture while the tangential magnetic field remains constant. The axial distribution of the tangential magnetic field has a Freshnel type behavior but unlike the electric field has no amplitude variation in the aperture as the aperture changes in diameter. Verification of the electromagnetic Babinets principle was obtained from the vector sum of the complementary fields. The research was supported by Bureau of Ships contract at the Antenna Laboratory, University of California, Berkeley, California.

K11. Cyclotron Methods for Producing Irradiation Effects in Materials. H. P. YOCKEY, M. R. JEPPSON, AND C. D'A. HUNT, *North American Aviation, Inc.*—Experimental methods of maintaining a desired temperature in solid material during irradiation with 35-Mev alphas, 19-Mev deuterons, and 8-Mev protons from the Berkeley 60-in. cyclotron will be described. Low temperatures are maintained by means of refrigerated helium recirculated in a closed system. The present system allows a 10°C rise per microampere. The base temperature at the sample is 100°K so that samples run at about 125°K during irradiation. A new refrigeration system includes a

pumped liquid nitrogen trap which will allow ½°C rise per μamp and will have a base temperature of about 70°K. A target box has been built in which samples are mounted on a turret and are rotated into the beam in succession without breaking the cooling system. Samples can be irradiated at controlled temperatures from 300°C to 2000°C. Because of beam current instability it is necessary to utilize a servo system which can correct for a temperature fall of 50°C per sec. The beam intensity and distribution is measured by a current integrator and by activation of bismuth foil. The specimen irradiation is made uniform by oscillating the specimen with a cam.

K12. The Effect of Cyclotron Bombardment of the Physical Properties of Metals.* A. B. MARTIN, S. B. AUSTERMAN, R. R. EGGLESTON, J. F. MCGEE, AND M. TARPINIAN, *North American Aviation, Inc.*—Samples of aluminum, copper, and the order-disorder alloys, AuCu and $AuCu_3$, have been irradiated with the alpha-particle beam of the Berkeley 60-in. cyclotron and the effects of such irradiations on several physical properties have been investigated. Measurements made during the irradiations while the sample temperature was held at −150°C, revealed large changes in the electric resistivity of all of these materials. Preliminary annealing studies indicated that these irradiation-induced resistivity changes began to anneal out at temperatures as low as −80°C. Room temperature measurements were made before and after each bombardment on the electric resistivity, temperature coefficient of resistivity, hardness, dimensions, and lattice parameters. Aluminum showed no appreciable change in any of these properties. Copper retained an appreciable increase in hardness at room temperature, but showed no other significant effects as a result of irradiation. Ordered samples of both AuCu and $AuCu_3$ retained large changes in electric resistivity, temperature coefficient of resistivity, and lattice parameters, similar to the changes that are observed in an order-disorder transformation. Disordered samples of these alloys showed only small changes in these properties after irradiation. An increase in hardness was observed in both the ordered and the disordered materials.

* This paper is based on work performed for the AEC.

MEETING OF THE DIVISION OF FLUID DYNAMICS

FRIDAY MORNING AT 9:00

Room 147, Business Administration and Economics

(J. G. KIRKWOOD presiding)

Forty-five minutes will be allowed for presentation and fifteen minutes for the discussion of each paper.

Turbulence, Theory and Experiment

L1. On Correlation Problems in a Model of Turbulence. J. M. BURGERS, Delft, Holland.

L2. On Recent Developments in the Statistical Theory of Turbulence. C. C. LIN, *Massachusetts Institute of Technology.*

L3. Experimental Investigations of Turbulent Flow. H. LIEPMANN, *California Institute of Technology.*

FRIDAY AFTERNOON AT 2:00

Room 147, Business Administration and Economics

(H. LEIPMANN presiding)

Hydrodynamics of Rarefied Gases

M1. Solution of the Boltzmann Equation in the Theory of Non-Uniform Gases. H. GRAD, *New York University.*

M2. Recent Results on Fluid Flow and Heat Transfer in Rarefied Gases. E. D. KANE, *University of California, Berkeley.*

M3. A Comparison of Theory and Experiment for High Speed Free Molecule Flow. JACKSON R. STALDER, GLEN GOODWIN, AND MARDUS O. CREAGER, *Ames Aeronautical Laboratory NACA.*

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Post, R. F. and N. S. Shiren—G6
Regener, Victor H.—I1
Rinehart, John S.—H12
Rogers, F. T., Jr.—K4
Rose, Jack W.—C6
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Sagane, R. and Peter C. Giles—E7
Schecter, L.—E3
Schiff, L. I. and R. F. Post—G7
Schrank, Glen E. and J. Reginald Richardson—J3
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Serber, Robert—A6
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Shook, G. B.—H11
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Thomas, R. G.—J11
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Violet, Charles E., F. C. Gilbert, and Walter H. Barkas—G14
Wallin, W.—K2
Wei, Yung Tsioh—H6
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Whaling, Ward and C. W. Li—J12
Wheeler, John A.—I3
Wheeler, John A. and John Toll—G4
Wilkening, M. H.—F3
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